NON-INVASIVE METHODS FOR THE INVESTIGATION OF SOFT TISSUE INJURY IN THE EQUINE LIMB: DIAGNOSTIC ULTRASONOGRAPHY AND MICROWAVE THERMOGRAPHY.

VOLUME TWO.

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CHAPTER 4.

A COMPARISON OF ULTRASONOGRAPHIC AND AIR TENDINOGRAPHIC FINDINGS IN THE DIGITAL FLEXOR TENDONS AND ASSOCIATED STRUCTURES IN THE HORSE.

SECTION 4.1. INTRODUCTION AND AIMS OF THE STUDY.

Ultrasonography and air tendinography are both imaging methods applicable to the equine limb. The aim of this study was to compare the results of two techniques in the evaluation of the superficial digital flexor tendon and peritendinous tissues in normal horses and clinical cases of superficial digital flexor tendon injury and to establish if the quantitative ultrasonographic and tendinographic parameters were accurate by comparison of the estimated dimensions with specimens obtained at post-mortem examination.

SECTION 4.2. MATERIALS AND METHODS.

Animals.

Six normal horses of Thoroughbred or Thoroughbred cross breed which had no clinical evidence of superficial digital flexor tendon injury were examined (Cases 4.1 to 4.6). A further seven horses were selected which had clinical signs associated with superficial digital flexor tendon injury: elevated skin temperature and palmar swelling in the metacarpal region. Three of these cases had bilateral injuries, and, therefore, the study included examinations performed on the ten affected limbs in these cases (Cases 4.7 to 4.13).

Ultrasonographic Examination

The hair was clipped and shaved from the palmar, palmar lateral and palmar medial aspects of the limb from the level of the accessory carpal bone to the distal pastern in the normal horses and to the fetlock joint in cases

4.7, 4.8 and 4.12 and echolucent gel was applied. An ultrasonographic unit equipped with a 7.5 MHz linear array transducer was used in all the studies. Longitudinal images of the palmar soft tissue structures of the metacarpal region were obtained in all horses. Transverse images of the palmar soft tissue structures of the metacarpal and proximal phalangeal regions were obtained in all normal limbs and abnormal cases 4.8, 4.12 and 4.13 (proximal and distal ultrasonograms). In the remaining abnormal cases only the metacarpal structures were imaged (proximal ultrasonograms). The superficial and deep digital flexor tendons, the inferior check ligament and the suspensory ligament and the proximal digital sheath were evaluated in the proximal ultrasonograms and the superficial and deep digital flexor tendons, the distal portion of the digital sheath, annular ligament and the straight sesamoidean ligament were evaluated in the distal ultrasonograms. The real time images and two frozen images obtained at levels approximately 220 and 300 mms distal to the accessory carpal bone were recorded on video tape. Dorsal to palmar measurements of the superficial and deep digital flexor tendons were obtained from the video tape using an electronic calliper system. The appearance and echogenicity of the tendons and surrounding soft tissues were evaluated subjectively.

Radiographic Technique.

The radiographs were obtained post-mortem in all normal horses (Cases 4.1 to 4.6) and in cases 4.7 and 4.11. The remaining animals were sedated using a combination of detomidine[1] and butorphenol[2], the skin was prepared surgically and 50 to 100 mls of air was inserted into the digital sheath using an 18 gauge 1.5 inch hypodermic needle with a three way tap which was attached following placement of the needle between the deep digital flexor tendon and the suspensory ligament in a distal direction. Air, 200 to 300 mls, was inserted subcutaneously at two sites: in the proximal and distal palmar metacarpal regions. Lateral-medial radiographs of the distal limb in an extended position were obtained following inflation of the digital sheath and in extended and flexed positions following the subcutaneous insertion of air. A film focal distance of 36 inches and 30 by 40 cms^2 screen film were used and the kilovolts and milliamperes per second were 40 and 4, respectively. The radiographs were reviewed subjectively and the superficial and deep digital flexor tendons, the inferior check ligament and the suspensory ligament, the fibrocartilages of the metacarpophalangeal joint and the proximal digital sheath were evaluated in the proximal air tendinograms. The superficial and deep digital flexor tendons, the distal portion of the digital sheath, annular ligament, the straight sesamoidean ligament and the fibrocartilages of the proximal interphalangeal joint were evaluated in the distal air

[1] Domosedan, Norden, [2] Torbugesic, C Vet Ltd.

tendinograms. The following measurements were recorded: the dorsal to palmar thicknesses of the total palmar soft tissues, the superficial and deep digital flexor tendons at the distal extremity of the second and fourth metacarpal bone and the level of the proximal sesamoid bones; the dorsal to palmar thickness of the third metacarpal bone at the distal extremity of the second and fourth metacarpal bone. These figures were corrected for radiographic magnification by multiplication by 0.91, a constant calculated by attaching a metal pin of known length to the dorsal part of the metacarpal bone while obtaining two of the normal radiographs and measurement of the radiographic estimation of the pin.

Following this procedure, a course of broad spectrum antibiotic[3] and tetanus antitoxin were administered to the live animals. In addition, support bandages were applied to both limbs and the horses were walked in hand for ten minutes twice daily until air could no longer be detected by palpation of the region.

Post-Mortem Evaluation.

Post-mortem examination of the superficial digital flexor tendon was performed in Cases 4.1 - 4.6, 4.7, 4.10 and 4.12, and of the deep digital flexor tendon in Cases 4.1, 4.2, 4.3, 4.6, 4.7, 4.10 and 4.12. Prior to examination of the tendons, the limbs were removed proximal to the carpal joint and following removal of the skin, the levels of the distal extremities of the

[3] Tribrissen Oral Paste, Coopers Animal Health Ltd.

second and fourth metacarpal bone and of the proximal sesamoids were marked. The tendons were removed by section at points proximal to the carpus and distal to the distal interphalangeal joint. The dorsal to palmar thickness of the flexor tendons were recorded using callipers at each of the marked levels. The gross appearance of the tendon was evaluated and sections were made at 2 cm intervals so that the internal structure could be inspected. Histological sections of the abnormal tendons were obtained and the results of these examinations are recorded in Chapter 3.

Mathematical And Statistical Analysis.

The ratios of the dorsal to palmar dimension of the deep digital flexor tendon to that of the superficial digital flexor tendon at both measurement points were calculated for each procedure.

The estimated tendinographic and ultrasonographic dimensions were compared with the corresponding measurement on the gross post-mortem specimens and the correlation coefficients of each group of data and of the radiographic estimation of total soft tissue thickness to metacarpal bone thickness in the normal limbs were calculated.

The minimum, maximum and mean dimensions of each ultrasonographic and air tendinographic parameter were established in the normal limbs. The number of abnormal cases which had dimensions outwith the normal range at one or both measurement sites of the superficial digital flexor tendon was determined and these data were used to calculate the sensitivity of each technique based on the measurement of these parameters. In addition, the sensitivity of the techniques when a positive diagnosis was based on the deep to superficial digital flexor tendon dimension ratio was determined.

SECTION 4.3. RESULTS.

The identification, breed and ages of the normal horses used in this study are recorded in Table 4.1 and the identification, breed and ages of the horses with superficial digital flexor tendon injury are recorded in Table 4.2 with details of the site and severity of the superficial digital flexor tendon injury based on the findings of clinical examination.

Qualitative And Subjective Assessment Of The Proximal Ultrasonograms And Air Tendinograms.

Superficial Digital Flexor Tendon.

The subjective assessments of the ultrasonograms and air tendinograms of the superficial digital flexor tendon in the abnormal cases are listed in Table 4.3.

The normal ultrasonographic findings in the superficial digital flexor tendon has been described in Chapter 2 and the findings are illustrated in Figs. 2.2., 2.4, 2.5., 2.6. and 2.7. The quality of visualization of the majority of structures was better in the ultrasonographic studies than in the air tendinograms in both normal and abnormal limbs. The separation of the superficial digital flexor tendon and the skin was good in half of the normal tendinograms with the exceptions of Cases 4.1. (right), 4.2. (left), 4.4. (left), 4.5. (left), 4.5. (right), 4.6. (right) in which there were localised areas in which the skin was not clearly defined from the underlying tendon (Figs. 4.1 and 4.2). Similarly, the skin and tendon borders could

CASE NO.	BREED	AGE (YEARS)
4.1	TB	12
4.2	TBX	15
4.3	TBX	20
4.4	TBX	5
4.5	TB	4
4.6	TB	20

TABLE 4.1. IDENTIFICATION, BREED AND AGE OF NORMAL HORSES INCLUDED IN THE STUDY.

CASE NO	BREED	AGE (years)	LOCATION	SEVERITY	DURATION	COMMENTS
4.7	TB	7	L/MID	MILD	3 DAYS	
4.7	TB	7	R/ALL	SEVERE	3 DAYS	RECURRENCE
4.8	PONY	12	L/MID	MILD	4 WEEKS	CONCURRENT CHECK LIGAMENT INJURY.
4.9	TB	7	L/MID	MILD	4 WEEKS	
4.9	TB	7	R/DISTAL	MILD	4 WEEKS	
4.10	TB	8	L/ALL	MODERATE	6 WEEKS	
4.10	TB	8	R/ALL	MODERATE	6 WEEKS	
4.11	TB	7	R/DISTAL	MILD	6 WEEKS	RECURRENCE
4.12	TB	8	R/MID	MILD	8 DAYS	
4.13	TB	7	R/ALL	SEVERE	15 MONTHS	

TABLE 4.2. IDENTIFICATION, BREED AND AGE OF HORSES WITH SUPERFICAL DIGITAL FLEXOR TENDON INCLUDED IN THE STUDY AND THE LOCATION, SEVERITY AND DURATION OF THEIR INJURIES.

TB = Thoroughbred, TBX = Thoroughbred cross. Location describes the limb and thirds of the tendon affected.

FIG. 4.1. A NORMAL AIR TENDINOGRAM OF THE PALMAR METACARPAL STRUCTURES ILLUSTRATING THE SUPERFICIAL (1) AND DEEP (2) DIGITAL FLEXOR TENDONS, THE INFERIOR CHECK LIGAMENT (3) THE SUSPENSORY LIGAMENT (4), AND THE THIRD METACARPAL BONE (5).

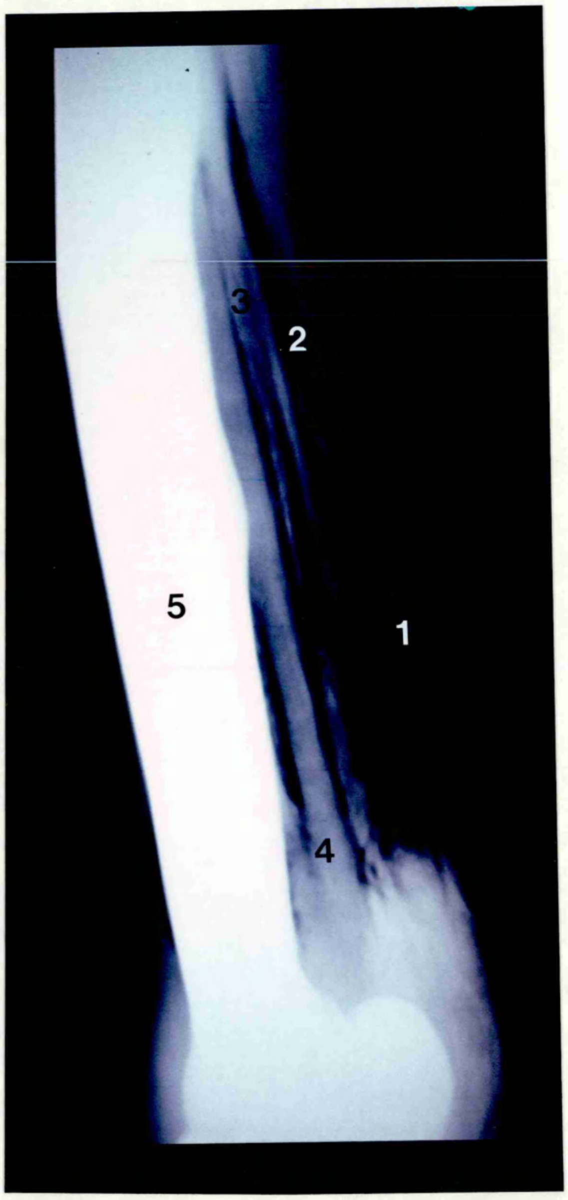
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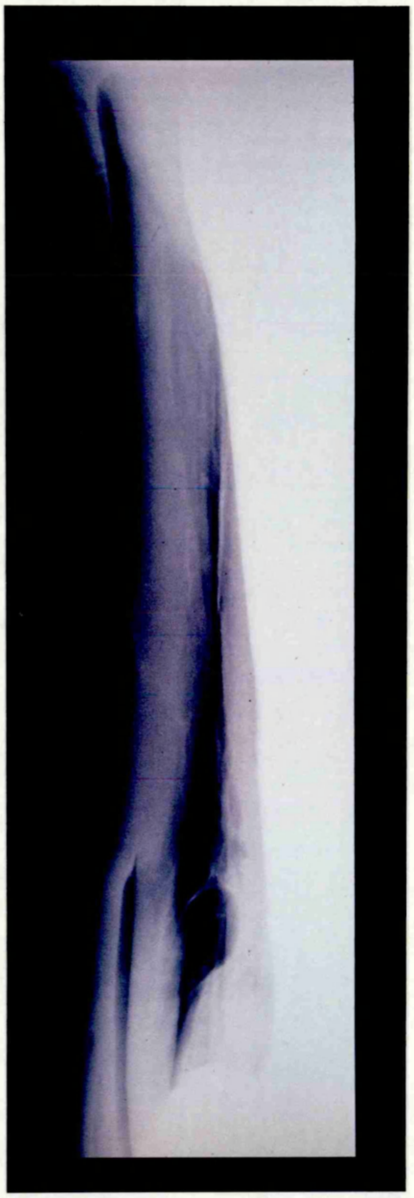
FIG. 4.2. A NORMAL AIR TENDINOGRAM OF THE PALMAR METACARPAL STRUCTURES IN WHICH THE SEPARATION BETWEEN THE SKIN AND FLEXOR TENDONS IS INSUFFICIENT TO DELINEATE THE SEPARATE SOFT TISSUE STRUCTURES.



not be defined in all abnormal cases with localised areas of non-separation in Cases 4.7. (right), 4.9. (left), 4.10. (left), 4.11. (right) and 4.12 (left) (Fig. 4.3). In Case 4.11. (right), there was a flocular opacity overlying the tendons in the proximal and mid metacarpal regions (Fig. 4.3). In Case 4.10 (right) there was a similar flocular opacity obscuring the tendons in the distal metacarpal region and there was an unusual soft tissue structure lying palmar to the superficial digital flexor tendon (Fig. 4.4). In Cases 4.8. (left) and 4.9. (right), localised areas of the palmar aspects of the superficial digital flexor tendon appeared to be irregular (Fig. 4.5). In the majority of the normal and abnormal ultrasonograms, the superficial digital flexor tendon appeared to be distinct from the overlying skin (Figs. 2.2, 2.4., 2.5., 2.6. and 2.7). In both Cases 4.10 (right) and 4.13 (right), an echogenic structure of 2 - 3 mms thickness was apparent between the skin and the superficial digital flexor tendon in the distal third of the metacarpal region (Fig. 4.6).

The superficial digital flexor tendon was not distinct from the deep digital flexor tendon in its most proximal portion in any of the air tendinograms (Fig. 4.1). In general, this structure could be imaged most clearly in the mid metacarpal region in the air tendinograms (Fig. 4.1). Nevertheless, in ten normal cases, it could not be clearly defined from the deep digital flexor tendon in the mid portion

FIG. 4.3. AN AIR TENDINOGRAM FROM CASE 4.11: THERE IS A FLOCULAR OPACITY OVERLYING THE TENDONS IN THE PROXIMAL AND MID METACARPAL REGIONS (>>).

FIG. 4.4. AN AIR TENDINOGRAM FROM CASE 4.10: THERE IS A FLOCULAR OPACITY OVERLYING THE TENDONS IN THE DISTAL METACARPAL REGION (>>) AND THE DELINEATION OF THE SUPERFICIAL AND DEEP DIGITAL FLEXOR TENDONS IS POOR.

FIG. 4.5. AN AIR TENDINOGRAM FROM CASE 4.8: THE INFERIOR CHECK LIGAMENT IS ENLARGED (1) AND THE PALMAR ASPECT OF THE SUPERFICIAL DIGITAL FLEXOR TENDON IS ROUGHENED (>>).

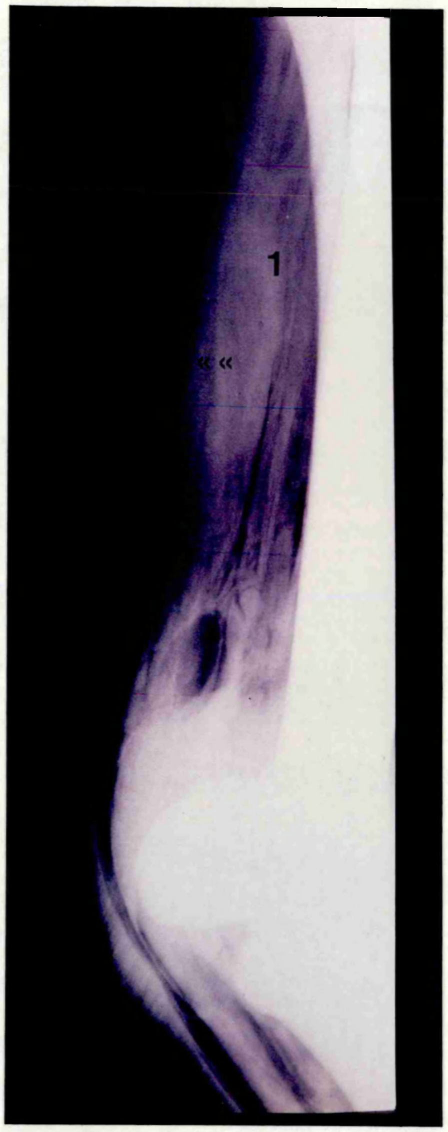

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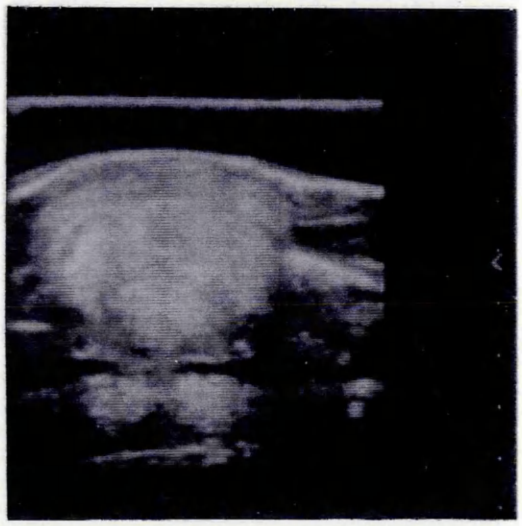
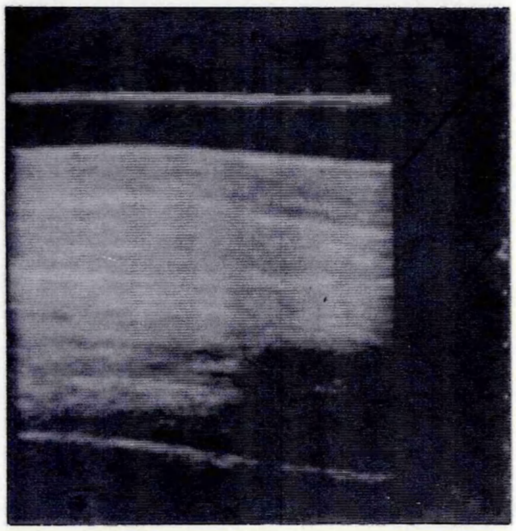
FIG. 4.6. TRANSVERSE (UPPER) AND LONGITUDINAL (LOWER) ULTRASONOGRAMS OF THE DISTAL THIRD OF THE PALMAR METACARPAL REGION OF CASE 4.10: AN ECHOGENIC STRUCTURE LIES BETWEEN THE SKIN AND THE SUPERFICIAL DIGITAL FLEXOR TENDON AND THE BORDER BETWEEN THE SUPERFICIAL AND DEEP DIGITAL FLEXOR TENDON IS INDISTINCT.





[inadequate: Cases 4.1 (left), 4.2 (left), 4.2 (right), 4.3 (left), 4.3 (right), 4.5 (right), 4.6 (left); partial visualization: Cases 4.4 (left), 4.5 (left), 4.6 (left)]. In ten normal air tendinograms the superficial and deep digital flexor tendons could not be distinguished from one and other in the distal portion [inadequate: 4.1 (left), 4.2 (left), 4.5 (left), 4.6 (left) and 4.6 (right); partial visualization: Cases 4.2 (left), 4.3 (right), 4.4 (left), 4.4 (right) and 4.5 (left), Fig. 4.2]. Equally, in six of the abnormal air tendinograms the superficial digital flexor could not be clearly defined from the deep digital flexor tendon in the mid portion [inadequate: Cases 4.10 (right), 4.11 (right), 4.12 (right) and 4.13 (right); partial visualization: Cases 4.7 (left) and 4.8 (left), Figs. 4.3 and 4.4)] and in nine of the air tendinograms these structures were either partially or inadequately defined in the distal portion [inadequate: Cases 4.7 (left), 4.7 (right), 4.10 (right), 4.11 (right) and 4.12 (right); partial visualization: Cases 4.9 (left), 4.9 (right), 4.10 (left), 4.13 (right), Figs. 4.3 and 4.4].

The superficial and deep digital flexor tendons could be clearly imaged in both normal and abnormal ultrasonograms except in Cases 4.10 (left) and 4.12 (right) in which the border between the superficial and deep digital flexor tendons was indistinct at various points along their lengths in the ultrasonograms (Figs. 2.2, 2.4, 2.5, 2.6, 2.7 and 4.6).

In all the normal cases, the echogenicity of the superficial digital flexor tendon was even throughout its length (Figs. 2.2, 2.4, 2.5, 2.6 and 2.7). The echogenicity of the lesions within the superficial digital flexor tendon are listed in Table 4.3. Case 4.11 (right) was unusual in that the majority of the tendon had a heterogeneous echogenicity consistent with chronic tendinitis and, in the distal third, there was a small anechoic lesion more typical of a recent reinjury of the tendon (Fig. 4.7). These findings were consistent with the clinical history of the case (Table 4.2).

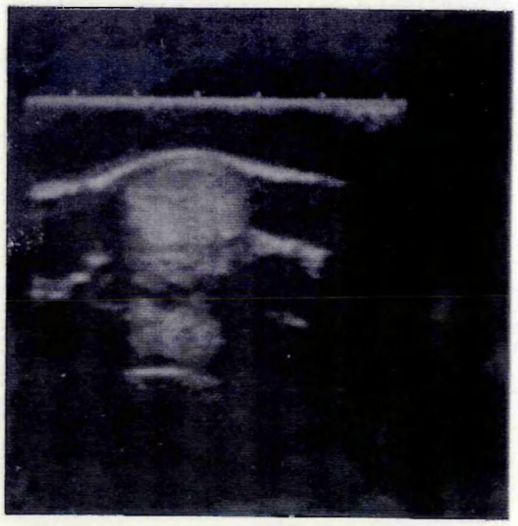
Deep Digital Flexor Tendon and Inferior Check Ligament.

The deep digital flexor tendon could be most clearly imaged in the mid portion in the majority of the proximal air tendinographic studies. The separation between the inferior check ligament and the deep digital flexor tendon was incomplete in the majority of the air tendinograms whereas, these two structures were individually well-defined on the ultrasonograms (Figs. 4.1, 4.2 and 4.5). The exception was Case 4.8 (left), in which the inferior check ligament was enlarged, its borders extended laterally and medially, and on its palmar aspect the separation between the ligament and the deep digital flexor tendon was obliterated (Fig. 4.8).

Suspensory Ligament.

The body of the suspensory ligament was clearly imaged in the majority of air tendinograms, but the branches

FIG. 4.7. ULTRASONOGRAMS FROM CASE 4.11: THE TRANSVERSE IMAGE (UPPER) FROM THE MID METACARPAL REGION SHOWS THAT THE ECHOGENICITY OF THE TENDON IS HETEROGENEOUS WITH BOTH HYPOECHOIC AND HYPERECHOIC AREAS TYPICAL OF A LONG-STANDING LESION. THE LONGITUDINAL ULTRASONOGRAM (LOWER) ILLUSTRATES THAT THERE IS AN ANECHOIC AREA IN THE DISTAL THIRD OF THE METACARPAL REGION (>>) REPRESENTING A MORE RECENT INJURY.



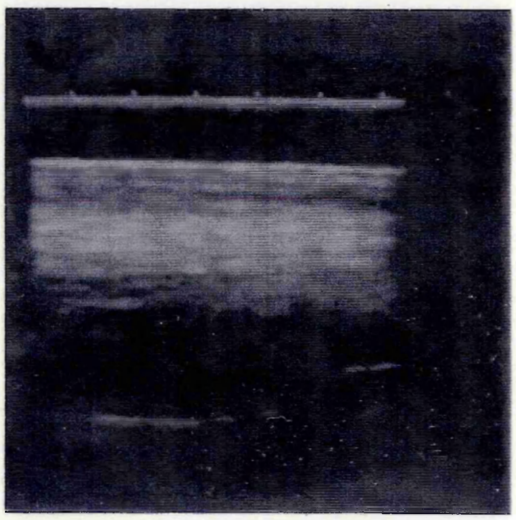
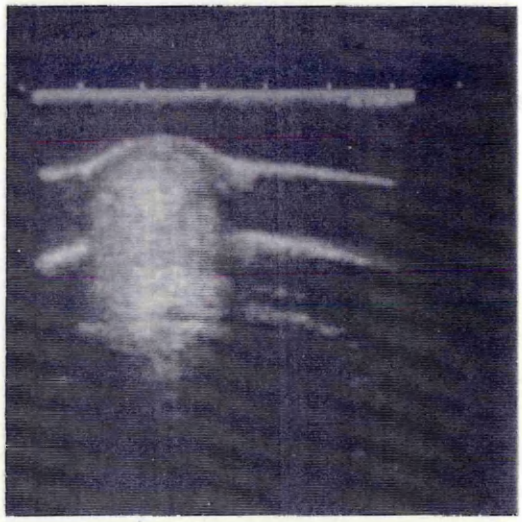
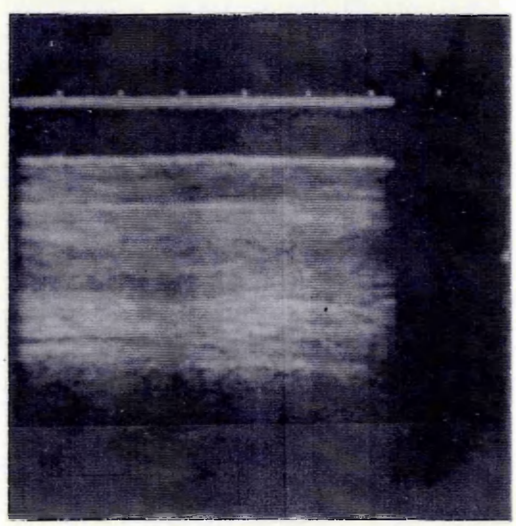


FIG. 4.8. THE ULTRASONOGRAPHIC FINDINGS IN CASE 4.8: THE INFERIOR CHECK LIGAMENT IS ENLARGED IN ALL THESE IMAGES OF THE MID METACARPAL REGION AND THE BORDERS BETWEEN THE SUPERFICIAL AND DEEP DIGITAL FLEXOR TENDON AND THE INFERIOR CHECK LIGAMENT ARE INDISTINCT. AN ANECHOIC AREA IS APPARENT WITHIN THE SUPERFICIAL DIGITAL FLEXOR TENDON IN THE MIDDLE AND LOWER IMAGES.





were not visible due to the overlying fibrocartilages of the metacarpophalangeal joint (Fig. 4.1). Both the body and the branches of the suspensory ligament could be imaged on the ultrasonograms.

Digital Sheath.

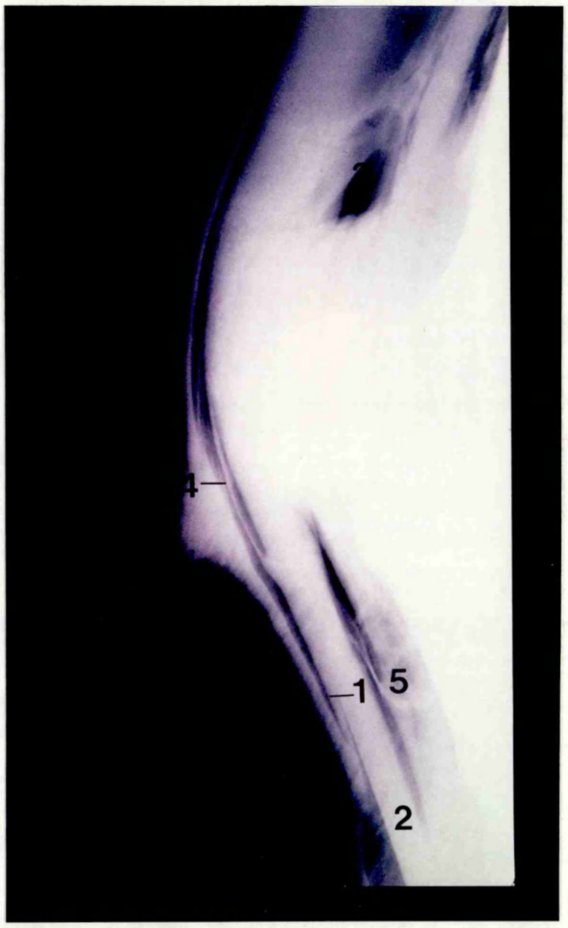
The proximal digital sheath was visualised in all air tendinograms but it was apparent on ultrasonographic examination in only eight of the twelve normal horses (Fig. 4.1). It was only partially visualised in two abnormal air tendinograms but was not clearly defined in one abnormal air tendinogram.

Qualitative and subjective assessment of the distal ultrasonograms and air tendinograms.

Superficial and Deep Digital Flexor Tendon.

The normal ultrasonographic findings on the palmar aspect of the first phalangeal region have been described in Chapter 2 and are illustrated in Fig. 2.8. In the distal ultrasonograms the visualization of the superficial and deep digital flexor tendons was excellent, although each structure in the area had to be examined separately to provide an acceptable image. Whereas, in the distal tendinograms the superficial digital flexor tendon was good in only seven of the 22 studies (Fig. 4.9). In contrast, the visualization of the deep digital flexor tendon was better and in eleven normal and six abnormal tendinographic studies the deep digital flexor tendon could be clearly seen (Fig. 4.9).

FIG. 4.9. A NORMAL AIR TENDINOGRAM OF THE METACARPOPHALANGEAL AND PHALANGEAL REGIONS ILLUSTRATING THE SUPERFICIAL (1) AND DEEP DIGITAL (2) FLEXOR TENDONS, THE DIGITAL SHEATH (3), THE ANNULAR LIGAMENT (4) AND THE STRAIGHT SESAMOIDEAN LIGAMENT (5).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Digital Sheath.

The visualization of the distal digital sheath was poor in all the ultrasonograms but was excellent in the air tendinograms in which that area was included on the radiograph (Figs. 2.8 and 4.9).

Annular Ligament.

The annular ligament was not well-defined in normal ultrasonograms and was partially observed in two abnormal cases and was well-defined in one. Conversely, the visualization of the annular ligament was considered to be inadequate in only five of the air tendinograms (Fig. 4.9).

Straight Sesamoidean Ligament.

The dorsal border of the straight sesamoidean ligament could not be discerned in any of the air tendinograms and, therefore, they were all described as having partial visualization (Fig. 4.9). Equally, visualisation of the straight sesamoidean ligament was described as partial in all the ultrasonograms because the origins and insertions of this ligament were difficult to image although the dorsal border could be seen clearly (Fig. 2.28).

Fibrocartilages Of The Proximal Interphalangeal Joint.

The fibrocartilages of the proximal interphalangeal joint could be seen clearly on all air tendinograms in which the area was included but these structures were not observed on the ultrasonograms.

Pathological Findings.

The normal status of the superficial digital flexor tendon was confirmed in Cases 4.1 - 4.6. The gross pathological findings in the abnormal cases are summarised in Table 4.3. The qualitative ultrasonographic diagnoses of superficial digital flexor tendon injury were confirmed in all cases. However, in two of these cases, the qualitative assessment of the air tendinographic examination were normal but mild superficial digital flexor tendon injuries were confirmed at post-mortem [Cases 4.10 (left) and 4.12 (right)]. In both of these cases, the injury represented the less severe of a bilateral injury.

Quantitative Assessment of Ultrasonograms, Air Tendinograms and Post Mortem Specimens.

The data which were recorded from the normal ultrasonographic and tendinographic studies and the tendons obtained from the cadavers are listed in Appendix 4.1. and those recorded from abnormal studies are included in Appendix 4.2. All the possible measurements were obtained from the ultrasonograms whereas only 128 out of a possible 154 could be recorded from the air tendinograms. The remainder could not be determined because the structures could not be visualized clearly.

The total soft tissue thicknesses and third metacarpal bone thicknesses from the normal air tendinograms and the correlation coefficients which were obtained when the soft tissue and bone thicknesses were

CASE NO.	LIMB	ULTRASONOGRAPHIC FINDINGS. ECHOGENICITY OF SDFT LESION	LOCATION	AIR TENDINOGRAPHIC FINDINGS	POST MORTEM FINDINGS
4.7	LEFT	ANECHOIC	MID	NORMAL	SWOLLEN, HAEMORRHAGIC AREA IN MIDDLE
4.7	RIGHT	ANECHOIC/HYPOECHOIC	ALL	SWELLING DISTAL THIRD, NO S. AND DDFT SEPARATION	HAEMORRHAGIC AREA THROUGHOUT TENDON WITH FRAYED FIBRES IN DISTAL THIRD.
4.8	LEFT	ANECHOIC INDISTINCT BORDERS WITH I.C.F.	MID	NO SEPARATION IN MID THIRD	
4.9	LEFT	HYPOECHOIC	MID	MID SDFT ENLARGED	
4.9	RIGHT	HYPOECHOIC	DISTAL	DISTAL SDFT ENLARGED SKIN ADHESION MID THIRD	
4.10	LEFT	HYPO/HYPERECHOIC	ALL	NORMAL	PALE CENTRAL PORTION WITH SMALL WHIT
4.10	RIGHT	HYPO/HYPERECHOIC HYPOECHOIC, ENLARGED PARATENON	ALL DISTAL	NO S. AND DDFT SEPARATION DISTAL EXCESS SOFT TISSUE AND FLOCULAR APPEARANCE.	PALE CENTRAL PORTION WITH SMALL WHIT PARATENON IN DISTAL PORTION
4.11	RIGHT	ANECHOIC HETEROGENEOUS	DISTAL ALL	NO S. AND DDFT SEPARATION, FLOCULAR APPEARANCE.	
4.12	RIGHT	ANECHOIC	MID	NORMAL	HAEMORRHAGIC LESION IN CENTRE OF MID
4.13	RIGHT	HYPO/HYPERECHOIC HYPOECHOIC, ENLARGED PARATENON	ALL DISTAL	NO. S. AND DDFT SEPARATION IN MID PORTION, PALMAR SWELLING DISTALLY.	

SDFT = superficial digital flexor tendon, DDFT = deep digital flexor tendon.

TABLE 4.3. ULTRASONOGRAPHIC, AIR TENDINOGRAPHIC AND GROSS PATHOLOGICAL FINDINGS IN CASES OF SUPERFICIAL DIGITAL FLEXOR TENDON INJURY.

related are recorded in Table 4.4 and these values indicate that there was no significant relationship between the amount of soft tissue and the bone thickness within the normal group. The values for these measurements in abnormal tendinograms are listed in Table 4.5.

The dorsal to palmar thicknesses of the superficial digital flexor tendon which were recorded from the normal and abnormal ultrasonograms, air tendinograms and postmortem specimens are listed in Tables 4.6 and 4.7 and the values recorded by these means for the dorsal to palmar thickness of the deep digital flexor tendon are listed in Table 4.8. The range and means of the ratios of deep digital flexor tendon thickness to superficial digital flexor tendon are listed in Tables 4.9 and 4.10, respectively. There was considerable overlap between the ranges of normal and abnormal thicknesses.

The correlation coefficients for the estimated thicknesses for both techniques compared with the true dimension recorded at post-mortem examination were poor and these are listed in Table 4.11. Both the ultrasonographic and tendinographic dimensions had significant correlations with the post mortem findings but these figures indicated that the air tendinograms correlated most closely with the post-mortem dimensions and that the estimations obtained from the longitudinal ultrasonograms were the least accurate in both the normal and abnormal limbs.

	MINIMUM (mms)	MAXIMUM (mms)	MEAN (mms)
A	38	52	44.6
B	10	18	13
C	28	34	30.2

CORRELATION OF A AND C 0.254

CORRELATION OF B AND C 0.335

TABLE 4.4. THE RANGES AND MEANS OF THE TOTAL SOFT TISSUE AND THIRD METACARPAL BONE DORSAL-PALMAR THICKNESSES IN TEN NORMAL AIR TENDINOGRAMS.

	MINIMUM (mms)	MAXIMUM (mms)	MEAN (mms)
A	30	62	49.4
B	10	17	13.7
C	27	37	32.1

TABLE 4.5. THE RANGE AND MEANS OF THE TOTAL SOFT TISSUE AND THIRD METACARPAL BONE DORSAL-PALMAR THICKNESSES IN TEN ABNORMAL AIR TENDINOGRAMS.

A = Dorsal-palmar thickness of soft tissue at the level of the distal end of the second and fourth metacarpal bones

B = Dorsal-palmar thickness of soft tissue at the level of the proximal sesamoids

C = Dorsal-palmar thickness of third metacarpal bone at the level of the distal end of the second and fourth metacarpal bones

MINIMUM - MAXIMUM (MEAN) [mms].

	A.T.	**U.S.L.**	**U.S.T.**	**G.P.M.**
M.M.	5-6 (5.9)	3-9 (5.4)	3-7 (5)	5-8 (5.5)
n	10	12	12	12
P.S.	5-6 (5.5)	3-6 (4.2)	2-5 (3.2)	3-6 (4.2)
n	2	12	12	12

TABLE 4.6. THE RANGES AND MEANS OF THE DORSAL-PALMAR THICKNESS OF THE SUPERFICIAL DIGITAL FLEXOR TENDON IN NORMAL LIMBS.

MINIMUM - MAXIMUM (MEAN) [mms].

	A.T.	**U.S.L.**	**U.S.T.**	**G.P.M.**
M.M.	6-18 (10.2)	5-12 (7.4)	6-11 (8.5)	6-16 (11.5)
n	7	10	10	4
P.S.	2-6 (4)	4-10 (6.5)	4-9 (6.4)	4-8 (6.4)
n	2	10	10	4

TABLE 4.7. THE RANGES AND MEANS OF THE DORSAL-PALMAR THICKNESS OF THE SUPERFICIAL DIGITAL FLEXOR TENDON IN ABNORMAL LIMBS.

A.T. = Air Tendinography
U.S.L. = Longitudinal Ultrasonograms
U.S.T. = Transverse Ultrasonograms
G.P.M. = Gross Post-Mortem Examination
M.M. = mid metacarpal site
P.S. = proximal sesamoid site
n = sample size

MINIMUM - MAXIMUM (MEAN) mms.

	A.T.	**U.S.L.**	**U.S.T.**	**G.P.M.**
M.M.	9-15 (12.4)	7-13 (9.8)	7-14 (9.7)	10-12 (11.1)
n	17	22	22	11
P.S.	10-15 (12)	6-11 (8.8)	6-12 (9.1)	10-12 (11.3)
n	3	22	22	11

A.T. = Air Tendinography
U.S.L. = Longitudinal Ultrasonograms
U.S.T. = Transverse Ultrasonograms
G.P.M. = Gross Post-Mortem Examination
M.M. = mid metacarpal site
P.S. = proximal sesamiod site
n = sample size

TABLE 4.8. THE RANGES AND MEANS OF THE DORSAL-PALMAR THICKNESS OF THE NORMAL DEEP DIGITAL FLEXOR TENDONS.

MINIMUM - MAXIMUM.

	A.T.	**U.S.L.**	**U.S.T.**	**G.P.M.**
M.M.	1.5 - 2.16	0.87 - 2.4	1.42 - 2.66	1.25 - 2.4
n	10	12	12	8
P.S.	2 - 2.5	1.5 - 2.75	1.4 - 5	1.66 - 3.66
n	2	12	12	8

TABLE 4.9. THE RANGES OF THE DEEP : SUPERFICIAL DIGITAL FLEXOR TENDON RATIO IN NORMAL LIMBS.

MINIMUM - MAXIMUM.

	A.T.	**U.S.L.**	**U.S.T.**	**G.P.M.**
M.M.	0.72 - 2.33	0.91 - 1.42	1- 1.83	0.73 - 1.22
n	7	10	10	3
P.S.	1.83	1 - 2	1 - 2.4	1.66 - 3.66
n	1	10	10	3

TABLE 4.10. THE RANGES OF THE DEEP : SUPERFICIAL DIGITAL FLEXOR TENDON RATIO IN ABNORMAL LIMBS.

A.T. = Air Tendinography
U.S.L. = Longitudinal Ultrasonograms
U.S.T. = Transverse Ultrasonograms
G.P.M. = Gross Post-Mortem Examination
M.M. = mid metacarpal site
P.S. = proximal sesamiod site
n = sample size

	NORMAL	ABNORMAL	ALL
TENDINOGRAPHIC VALUES*			
CORRELATION	0.856	0.821	0.840
SIGNIFICANCE LEVEL	0.01	0.1	0.01
SAMPLE SIZE	22	5	27
ULTRASONOGRAPHIC VALUES			
LONGITUDINAL			
CORRELATION	0.811	0.537	0.662
SIGNIFICANCE LEVEL	0.01	0.05	0.01
SAMPLE SIZE	35	9	44
TRANSVERSE			
CORRELATION	0.808	0.783	0.701
SIGNIFICANCE LEVEL	0.01	0.01	0.01
SAMPLE SIZE	35	9	44

* correction factor = 0.91

TABLE 4.11. CORRELATION COEFFICIENTS OF TENDINOGRAPHIC AND ULTRASONOGRAPHIC VALUES WITH SIMILAR MEASUREMENTS IN GROSS SPECIMENS.

PARAMETER	ESTIMATED POSITIVES	TRUE POSITIVES	SENSITIVITY (%)
AIR TENDINOGRAPHY			
A > 52 mm	3	10	30
B > 18 mm	0	10	0
MID SDFT > 6 mm	6	8	75
DISTAL SDFT > 6 mm	3	5	60
MID DDFT:SDFT < 1.5	4	8	50
DISTAL DDFT:SDFT < 2	1	1	100
ULTRASONOGRAPHY - LONGITUDINAL			
MID SDFT > 9 mm	2	10	20
DISTAL SDFT > 6 mm	4	10	40
MID DDFT:SDFT < 0.87	0	10	0
DISTAL DDFT:SDFT < 1.5	3	10	30
ULTRASONOGRAPHY - TRANSVERSE			
MID SDFT > 7 mm	8	10	80
DISTAL SDFT > 5 mm	4	10	40
MID DDFT:SDFT < 1.42	7	10	70
DISTAL DDFT:SDFT < 1.4	4	10	40

A = total soft tissue thickness at the distal extremities of the second and fourth metacarpal bones
B = total soft tissue thickness at the proximal sesamoids
SDFT = superficial digital flexor tendon
DDFT = deep digital flexor tendon.

TABLE 4.12. THE SENSITIVITY OF TENDINOGRAPHY AND ULTRASONOGRAPHY FOR DIAGNOSIS OF SUPERFICIAL DIGITAL FLEXOR TENDON INJURY BASED ON THE DETECTION OF VALUES OUTWITH THE NORMAL RANGE.

The sensitivities of each technique based on the detection of a dorsal to palmar thickness outwith the normal range are listed in Table 4.12. The sensitivities were poor for all these techniques, which demonstrated that a positive diagnosis could not be predicted simply by the assessment of a single quantitative parameter.

Clinical Sequelae.

Following the ultrasonographic examinations, there were no adverse effects. The air which was injected into the limb for the tendinographic studies was detectable by digital palpation for a period of five to eight days after the examination. It tended to spread up the limb and could be detected around the carpus from the first day following insertion. In two cases (Cases 4.11 and 4.13), there was increased skin temperature in the fetlock region for three days after the study. In all cases, antibiotic therapy was continued until the subcutaneous air could no longer be palpated.

SECTION 4.4. DISCUSSION.

The radiographic examination of the flexor tendons produced disappointing definition of these structures in several of the normal and abnormal cases. Verschooten and De Moor had recommended general anaesthesia for this procedure and this may have improved the quality of the radiographs in the abnormal cases. Nevertheless, in the euthanased animals, the definition of the flexor tendons was not as distinct as that obtained by ultrasonographic examination and this difficulty has been encountered previously in a proportion of cases (Verschooten and De Moor, 1978). The lack of definition, which was observed in normal horses, cast doubt on the significance of ill-definition of the superficial and deep digital flexor tendons as an indication of peritendinitis in the abnormal horses.

The demonstration of peritendinous tissue palmar to the superficial digital flexor tendon was more successful and in these horses roughened borders of the palmar aspect of the tendon or, in one case, a distinct palmar soft tissue structure were visualised. The flocular appearance which was noted in Cases 4.10 (right) and 4.11 (right) has not been reported previously (Figs. 4.3 and 4.4). The ultrasonographic examinations in these cases and, in addition, in Cases 4.12 (right) were suggestive of excess peritendinous soft tissue and in Case 4.10 (right) this was confirmed at post-mortem examination (Fig. 4.6).

The information on the status of the superficial digital flexor tendon obtained from the air tendinograms simply reflected the shape of the tendon. The presence of superficial digital flexor tendon injuries was correctly diagnosed by ultrasonographic examination in all ten cases but, in two of these cases, the radiographic findings appeared to be normal and, therefore, the radiographic technique was not specific. In both of these instances, the lesions were very small and represented the less severe of bilateral injuries. Nevertheless, the clinical findings in both of these cases had been suggestive of superficial digital flexor tendon injury.

It was not possible to distinguish acute and chronic injuries on the basis of radiographic findings and this limitation has been noted previously (Verschooten and De Moor, 1978). The ultrasonographic findings vary with the age of the tendon injury and, in these cases, the echogenicity of the lesions increased with their duration (Genovese and others, 1985; Rantanen and others, 1985; Genovese and others, 1986; Genovese and others, 1987; Reef and others, 1988; Chapter 3). This limitation was well demonstrated in Case 4.11 in which the acute lesion could not be distinguished from the generalised enlargement associated with chronic tendinitis on radiographic examination. In contrast, ultrasonographic examination was more informative (Fig. 4.3).

Case 4.8 was unusual in that it was a pony which had suffered a injury to the inferior check ligament eighteen months previously and it was presented for examination as heat and swelling had recently appeared in the mid metacarpal region. The clinical history and findings were suggestive of an acute exacerbation of the inferior check ligament injury but both ultrasonographic and radiographic examination confirmed that there was an injury in the superficial digital flexor tendon (Figs. 4.5 and 4.8).

The total soft tissue thickness and third metacarpal bone dimension could be obtained in every horse and it has been suggested that measurement of the metacarpal bone would provide a standard with which to compare the soft tissue thickness in horses of different breeds and types but, in this study, there was no correlation between the soft tissue thicknesses and third metacarpal bone thickness (Table 4.4; Verschooten and De Moor, 1978). Equally, there was a wide range in the ratio of deep to superficial digital flexor tendon dimension within the group (Table 4.9). In their study of normal horses, Verschooten and De Moor (1978), found a constant relationship of 3.

It was not possible to record all the desired flexor tendon dimensions from the radiographs whereas all the ultrasonographic parameters were obtained but the radiographic measurements had the best correlation with the post-mortem findings (Table 4.11). The longitudinal ultrasonographic estimations were the least precise and this may have been due to the fact that the images may not have been recorded from the widest part of the tendon which was difficult to appreciate on longitudinal images.

The normal ultrasonographic and tendinographic dimensions of the superficial and deep flexor tendons were similar to, but not identical to, those reported previously and the differences may reflect a difference in the animal population (Tables 4.6 and 4.8; Verschooten and De Moor, 1978; Genovese and others, 1986). A considerable overlap was identified between the ranges of superficial digital flexor tendons in the normal and abnormal groups and, therefore, a single measurement could not be used to predict the correct diagnosis in either technique (Tables 4.6, 4.7 and 4.12). The mid metacarpal measurements appeared to have more diagnostic value than the distal metacarpal series. This is to be expected since the majority of lesions were located in the central metacarpal region (Tables 4.2, 4.3 and 4.12). Similarly, the total soft tissue thicknesses and the deep to superficial digital flexor tendon dimension ratios also demonstrated overlap between the normal and abnormal groups and these were not sensitive diagnostic criteria (Tables 4.4, 4.5, 4.9, 4.10 and 4.12).

The need for sedation, disposable materials, after care and antibiotics combined to make radiography more expensive and time consuming than ultrasonographic examination in the clinical cases. No long-lasting adverse effects were observed following these examinations. However, the air was detectable in the limb by palpation for several days. In previous studies, it has been stated that it generally disappeared within twenty-four hours (Verschooten and De Moor, 1978; Verschooten and Picavet, 1986).

In summary, the air tendinograms did not appear to add any further information to that available from ultrasonographic examination. Both techniques provided evidence of changes in dimension and shape of the superficial digital flexor tendon and subjective evidence of peritendinous disease. However, ultrasonographic examination was able to localise small lesions which were imperceptible by radiography and the changes in echogenicity of the lesion reflected their duration. The non-invasive nature of ultrasonographic examination further supports its use, in preference to air tendinography, as the technique of choice for evaluation of the superficial digital flexor tendon.

CHAPTER 5.

AN ULTRASONOGRAPHIC STUDY OF SUPERFICIAL DIGITAL FLEXOR TENDON INJURY IN HORSES.

SECTION 5.1. INTRODUCTION AND AIMS OF THE STUDY.

For centuries, flexor tendon injury has been recognised as a common occurrence in horses which are required to work at speed and there have been numerous descriptions of the eventual outcome of cases of superficial digital flexor tendon injury (Miles, 1875; Asheim and Knudsen, 1967; Nilsson and Bjorck, 1969; Nilsson, 1970; Knudsen, 1976; Webbon, 1979; Goodship and others, 1980; McKibbin and Paraschak, 1983; Whatmore and others, 1984; Vaughan and others, 1985; Bramlage, 1986; Genovese and others, 1987). However, the majority of these studies were directed at the investigation of a specific treatment regimen and details on the outcome of cases which were managed conservatively are not available. Further, with few exceptions, these authors reported the outcome of flexor tendon injury in groups of Standardbred racehorses or Thoroughbreds which were working on the flat and prognostic information generated from these groups cannot be extrapolated directly to animals which are worked and managed differently (Asheim and Knudsen, 1967; Nilsson and Bjorck, 1969; Nilsson, 1970; Knudsen, 1976; McKibbin and Paraschak, 1983; Whatmore and others, 1984; Bramlage, 1986). The incidence of flexor tendon injury is higher in Thoroughbred horses competing in National Hunt racing than in those racing on the flat (Evans, 1988). Nevertheless, studies on the eventual outcome in cases of superficial digital flexor tendon injury in National Hunt and point-to-point racehorses are limited in number (Webbon, 1979; Goodship and others, 1980; Vaughan and others, 1985).

The ultrasonographic appearance of both acute and chronic superficial digital flexor tendon injury has been reported previously (Spaulding, 1984; Genovese and others, 1985; Rantanen and others, 1985; Genovese and others, 1986; Genovese and others, 1987; Reef and others, 1988). Typically, superficial digital flexor tendon lesions have a reduced echogenicity which gradually increases as the lesion progresses and the normal fibrillar appearance in longitudinal images is disrupted in the acute stages and gradually reappears during the healing process (Genovese and others, 1985; Rantanen and others, 1985; Henry and others, 1986; Genovese and others, 1986; Genovese and others, 1987; Reef and others, 1988). However, to date, there have been no reports of investigations in which a group of individuals were monitored repeatedly by ultrasonographic examination throughout the course of their injuries.

The aims of this study were to document the ultrasonographic appearance of acute superficial digital flexor tendon injury and to relate this to the severity of the lesion; to establish which ultrasonographic features varied consistently throughout the course of healing and could thereby be used as parameters by which to assess tendon healing; to monitor a group of individuals throughout the chronic course of their injuries and to define if specific patterns of change in the ultrasonographic findings existed. Finally, the factors influencing the severity of the tendon lesion and eventual outcome of the cases was investigated in an effort to compile data on the prognosis for superficial digital flexor tendon injury in Thoroughbred racehorses competing over fences.

SECTION 5.2. MATERIALS AND METHODS.

Animals.

The animals which were included in this study were all Thoroughbreds which had sustained superficial digital flexor injuries during either National Hunt or point-to-point racing. They were referred for ultrasonographic examination by general practitioners, a number of whom were contacted on initiation of the study and informed of the need for suitable clinical material.

Clinical History and Examination.

The maximum available history was obtained from the owners and, in particular, details of the current and any previous tendon injuries and treatment were recorded. Clinical examination was confined to observation of the horses at a walk or a few strides of slow jog, visual examination of the limb, noting in particular, palmar swelling associated with the superficial digital flexor tendon and dorsiflexion of the metacarpophalangeal joint and palpation of the tendon with the limb weight-bearing and held in flexion to detect enlargement or increased temperature. Finally, the lateral and medial borders of the tendon were pinched to determine the response to painful stimuli. If the owners or trainers reported a degree of lameness which was not consistent with either the severity or the duration of the tendon injury they were advised to seek the opinion of their general practitioner or, when appropriate, the animals were referred for orthopaedic evaluation within the School.

Ultrasonographic Examination.

The limbs were prepared for examination by clipping and shaving the palmar aspect of the limb between the carpal and metacarpophalangeal joints and by application of echolucent gel. An ultrasonographic unit equipped with a 7.5 MHz linear array transducer and a echolucent stand-off block were used in this study. Transverse and longitudinal images of the soft tissue structure of the palmar aspect of the metacarpal region were obtained from 60 to 300 mm distal to the accessory carpal bone and frozen images of the sites 60, 140, 220 and 300 mms distal to the accessory carpal bone were recorded using a video recorder. In addition, images of the entire area were recorded in real-time for review. Both fore limbs were examined in this way on all occasions regardless if bilateral lesions were thought to be present or not.

Ultrasonographic Interpretation.

The length of the lesion was estimated and expressed in multiples of 20 mms. The percentage of the cross-sectional area of the tendon affected was estimated at the lesion's widest point and the location, echogenicity, distinctness of the lesion from the surrounding tendon and the distinctness of the superficial digital flexor tendon from the adjacent skin and deep digital flexor tendon, the presence and appearance of linear echoes on longitudinal images and the presence of peritendinous lesions were noted. The echogenicity of lesions was described as 1 = anechoic; 2 = hypoechoic; 3 = anechoic and hypoechoic; 4 = mixed hypoechoic areas; 5 = hyperechoic foci while the distinctness of the lesion was described as 0 = could not be discerned, 1 = difficult to discern with the whole tendon being heterogeneous; 2 = moderately difficult to discern with a slightly hypoechoic area present; 3 = obvious delineation with a well-defined hypoechoic area present; 4 = marked delineation with a large difference in echogenicity between lesion and rest of tendon. The linear echo arrangement was also allocated a grade: 0 = absent; 1 = minimal, short echoes; 2 = few, irregularly arranged linear echoes; 3 = numerous but irregular, shortened linear echoes; 4 = numerous linear echoes some of which were shortened and irregular; 5 = normal.

Assessment Of Severity.

The severity of the lesion was defined on the initial examination. The lesions were classified as mild, moderate or severe on the basis of the size of the lesion. Mild lesions comprised less than or equal to 50% of the cross-sectional area and were less than or equal to 100 mms in length. Moderate lesions were between 50 and 75% of the cross-sectional area and were between 100 and 160 mms in length. Severe lesions were greater than 75% of the cross-sectional area and were greater than 160 mms in length.

Examination Schedule.

Examinations were performed on the following occasions: as soon as possible after the injury, two, three, four, eight, twelve, sixteen, twenty-six, thirty-six, fifty-two and seventy-six weeks after injury. Thereafter, examinations were performed at six-monthly intervals. This schedule was modified according to the convenience of the owners or trainers of the horses and when it was appropriate for the management of the case additional examinations were performed. In some of the cases which were presented for examination between four and eight weeks after the initial injury, several examinations were performed in this period. Frequently, horses were not available on all the planned occasions and examinations which were performed within two weeks of twenty-six and thirty-six weeks and four weeks of fifty-two or seventy-six weeks were regarded as being performed on the nearest designated time period.

Treatment Regimens.

The clinical management of these cases was the responsibility of the referring practitioner.

Three basic treatment regimens were employed commonly and these were:

1. Conservative management consisting of variable periods of box rest, in-hand walking and pasture rest (54 cases).

2. Laser therapy which was administered for four minutes every second day for four weeks during which time the

horse was box rested, followed by four additional weeks of box rest and variable periods of pasture rest (ten cases).

3. Administration of 500 mgs polysulphated glycosaminoglycans[1] by the intratendinous or intramuscular route on six occasions three to four days apart during which time the horse was box rested and followed by four additional weeks of box rest with variable periods of pasture rest (17 cases).

The nine remaining cases were euthanased following ultrasonographic examination at the owners' request.

Evaluation Of Outcome.

The cases which were included in the study had injuries of at least nine months' duration at the conclusion of the study. The owners were contacted and the following information obtained:

1. Had the horse raced and if so how many times, how long was the total period of rest prior to commencement of training and had a tendon lesion recurred in the ipselateral or contralateral limb.
2. Had the horse commenced training but not raced, how long was the total period of rest prior to commencement of training and had a tendon lesion recurred in the ipselateral or contralateral limb.
3. Was the horse still resting in which case the outcome was classified as unknown.

[1] = Adequan, Pharmacia Ltd.

4. Had the horse been euthanased or retired to perform less strenuous work or to breed (these horses were classified together as the retired group).

5. Had the horse died, been euthanased or retired to less strenuous work for unrelated reasons.

Analysis Of Results: Ultrasonographic Findings.

Each ultrasonogram was reviewed retrospectively and the classification systems to define the ultrasonographic findings and the severity which are described above were applied.

At each time point described above, the frequency of observation of each grade of echogenicity, linear echo formation and lesion border distinctness were calculated. In some individuals, more than one examination was performed near to the designated time point and, in these cases, the ultrasonogram obtained nearest to the relevant time point was included in this analysis while the others were disregarded. In this way, the patterns of change of these parameters within the whole group were defined.

In addition, the data obtained from individual horses which had received multiple examinations over periods equal to, or in excess of, twenty-six weeks were examined to determine if there were consistent patterns of change associated with the severity of the lesion or the initial ultrasonographic appearance.

Analysis Of Results: Factors Influencing The Severity Of Superficial Digital Flexor Tendon Injury.

The animals were divided into the following subgroups on the basis of the severity of the superficial digital flexor tendon injury: horses which had unilateral mild lesions; horses which had bilateral mild lesions; horses which had unilateral moderate lesions; horses which had bilateral lesions, the most severe of which was moderate; horses which had unilateral severe lesions; horses which had bilateral lesions, the most severe of which was severe. The mean age of each classification of severity was calculated and the influence of age,sex and previous injury on the severity of the superficial digital flexor tendon lesion was determined by application of the Chi-Squared test and Fischer's exact test where the subgroups were small ($n < 5$).

Factors Influencing The Eventual Outcome In Superficial Digital Flexor Tendon Injury.

Three parameters were used as end-points to assess the eventual outcome of these cases and these were whether or not the animals were working or retired; the duration of the lay-off period between the initial injury and the return to training and the recurrence of superficial digital flexor tendon in the ipselateral or contralateral limb. The animals were divided into groups according to the classification of severity determined in the acute stages, the age, the sex, the history of previous tendon injury and the treatment regimen and the proportion of animals racing and training (working) or which had retired and the recurrence rate of superficial digital flexor tendon injury was determined for each subgroup and for the total group as a whole. The Chi-Squared and Fischer's exact tests were used to investigate if there were significant differences between the outcome in these various groups. The influence of these factors on the duration of the rest period required prior to commencing work was examined by one way analysis of variance.

SECTION 5.3. RESULTS.

A total of 90 horses were included in this study. The details of the age and sex, the history of previous injury and the ultrasonographic findings at each examination of each horse are listed in Appendix 5.1. The number of examinations of each horse ranged from one to 13, with the average number being five and animals were monitored for varying periods up to 110 weeks. There were 54 cases of unilateral tendon injury and 36 bilateral cases. The number of left and right fore superficial digital flexor tendon injuries were 65 and 61 respectively and thus, a total of 126 injured superficial digital flexor tendons were included in the study.

All of these horses were engaged in fast work prior to the onset of clinical signs. The clinical signs associated with flexor tendon injury were present in varying degrees in all cases. In the acute stages, the most consistent findings were of heat and swelling in the palmar metacarpal region. Marked lameness was not a consistent finding and was present only in the more severe lesions. Pain on palpation of the lateral and medial borders of the tendon was helpful in some cases but many horses responded equally to this stimuli in the normal contralateral limb and the response within the same limb would vary if the procedure was repeated several times. In chronic cases, clinical findings were felt to be less helpful as, although enlargement of the tendon was universally present to some degree, in the absence of heat or softness of the tendon there were no parameters by which to evaluate the tendon.

Five horses continued to be monitored after recurrence of an injury which had previously been included in the study. At that point they were considered as a new case and a new case number was allocated. These individuals were Cases 5.4/5.5, 5.29/5.30, 5.42/5.43, 5.44/5.45, 5.61/5.62.

Nine animals which are included in this study were euthanased shortly after sustaining superficial digital flexor tendon lesions at the owners request due to the severity of their tendon injuries or for economic considerations and most of these animals were included in the group which was described in Chapter 3 (Cases 5.62 to 5.70).

The remaining horses were treated conservatively (54 horses, Cases 5.3 - 5.6, 5.13 - 5.16, 5.25 - 5.33, 5.35, 5.38 , 5.40 - 5.51, 5.53, 5.56 - 5.61, 5.71 - 5.79, 5.81 , 5.82, 5.86 - 5.87), by polysulphated glycosaminoglycans administration (17 horses, Cases 5.1, 5.6, 5.8, 5.18 - 5.22, 5.23, 5.34, 5.36, 5.52, 5.54 - 5.57, 5.78, 5.80) and with therapeutic laser (ten horses, Cases 5.2, 5.9, 5.10, 5.12, 5.17, 5.23, 5.37, 5.39, 5.84, 5.90). The first aid therapy and periods of box and pasture rest varied from case to case, usually at the owners' convenience. Two horses were fired in addition to conservative treatment (Cases 5.15 and

5.29) and two horses were fired in addition to polysulphated glycosaminoglycans administration (cases 5.1 and 5.54).

Ultrasonographic Findings in Acute Tendon Injury.

The ultrasonographic findings which were observed in acute superficial digital flexor tendon injury were similar to those which have been described in Chapter 3, namely three distinct patterns: a discrete area of reduced echogenicity in the centre of the tendon; a complex pattern of anechoic and hypoechoic areas throughout the majority of the metacarpal region of the tendon and a diffuse reduction in echogenicity throughout the entire metacarpal region of the tendon.

Eighty acute lesions (63%) were discrete areas of reduced echogenicity which were usually located in the mid and/or the distal third of the metacarpal region. Thirty one of these were confined to the middle third while only three lesions were confined to the distal third alone and there were none located solely in the proximal third. Forty-one lesions extended between the middle and distal third and one horse had a lesion which was located in the proximal and middle third of the metacarpal region (Case 5.22). These discrete lesions usually had a central location although this was not necessarily in the exact geometric centre of the tendon. Some were located nearer to either the palmar or the dorsal aspect of the tendon while others were located either towards the lateral or medial border and, although their shape on transverse images tended to be circular or oval, this also varied slightly and a range of irregular shapes were observed.

The echogenicity of these discrete lesions and a further four which extended throughout all three thirds of the metacarpal region was graded as anechoic in 45 cases (13 mild; 29 moderate, 3 severe) and hypoechoic in 30 (20 mild, ten moderate) and five of the moderate lesions were combinations of anechoic and hypoechoic areas. These discrete lesions had distinct borders and no linear echoes present.

The remainder of the lesions examined in the acute stage (38) were also present in the proximal, middle and distal thirds of the metacarpal region of the superficial digital flexor tendon and they were complex, heterogeneous lesions with anechoic and hypoechoic regions (36 lesions, 30%) or, in two cases, diffuse reductions in echogenicity throughout the entire tendon were apparent (Cases 5.23 and 5.35). In all cases where marked enlargement of the tendon was present it tended to increase both on the palmar and medial borders so that it wrapped around the medial aspect of the deep digital flexor tendon.

In one case, two separate lesions could be visualised within the same tendon (Case 5.72; Fig. 5.1). A larger lesion was present in the mid and distal thirds of the tendon which was hypoechoic and an additional anechoic lesion was detected within the distal third

FIG. 5.1. ULTRASONOGRAPHIC FINDINGS IN CASE 5.72.

THIS HORSE HAD TWO DISTINCT LESIONS IN ITS RIGHT FORE SUPERFICIAL DIGITAL FLEXOR TENDON. THE LARGEST LESION WAS HYPOECHOIC, IT COMPRISED APPROXIMATELY 75 % OF THE CROSS-SECTIONAL AREA OF THE TENDON AND WAS LOCATED IN THE DORSAL AND CENTRAL ZONES OF THE TENDON (UPPER).

A SMALL ANECHOIC LESION WHICH WAS APPROXIMATELY 40 mms IN LENGTH WAS IDENTIFIED IN THE DISTAL THIRD OF THE METACARPAL REGION AND THIS WAS LOCATED IN THE LATERAL AND PALMAR ASPECT OF THE TENDON. IN THIS REGION THE LARGER LESION WAS ALSO PRESENT PRODUCING A REDUCTION IN ECHOGENICITY IN THE CENTRAL ZONE (LOWER).

located on the lateral aspect of the superficial digital flexor tendon.

Case 5.58 was also unusual: this horse sustained a complete rupture of the superficial digital flexor tendon in the mid metacarpal portion. Two separate, fragmented ends could be imaged and in the mid metacarpal areas there was an 80 mms defect in which the deep digital flexor tendon was located immediately beneath the skin (Fig. 5.2). On the medial aspect of the deep digital flexor tendon in this area, hypoechoic tissue was present which was assumed to represent fragments of the superficial digital flexor tendon. The areas proximal and distal to this had an hypoechoic lesion within the superficial digital flexor tendon but there was surprisingly little peritendinous swelling in this case. The overlying skin was intact and a relatively small area of bruising was apparent.

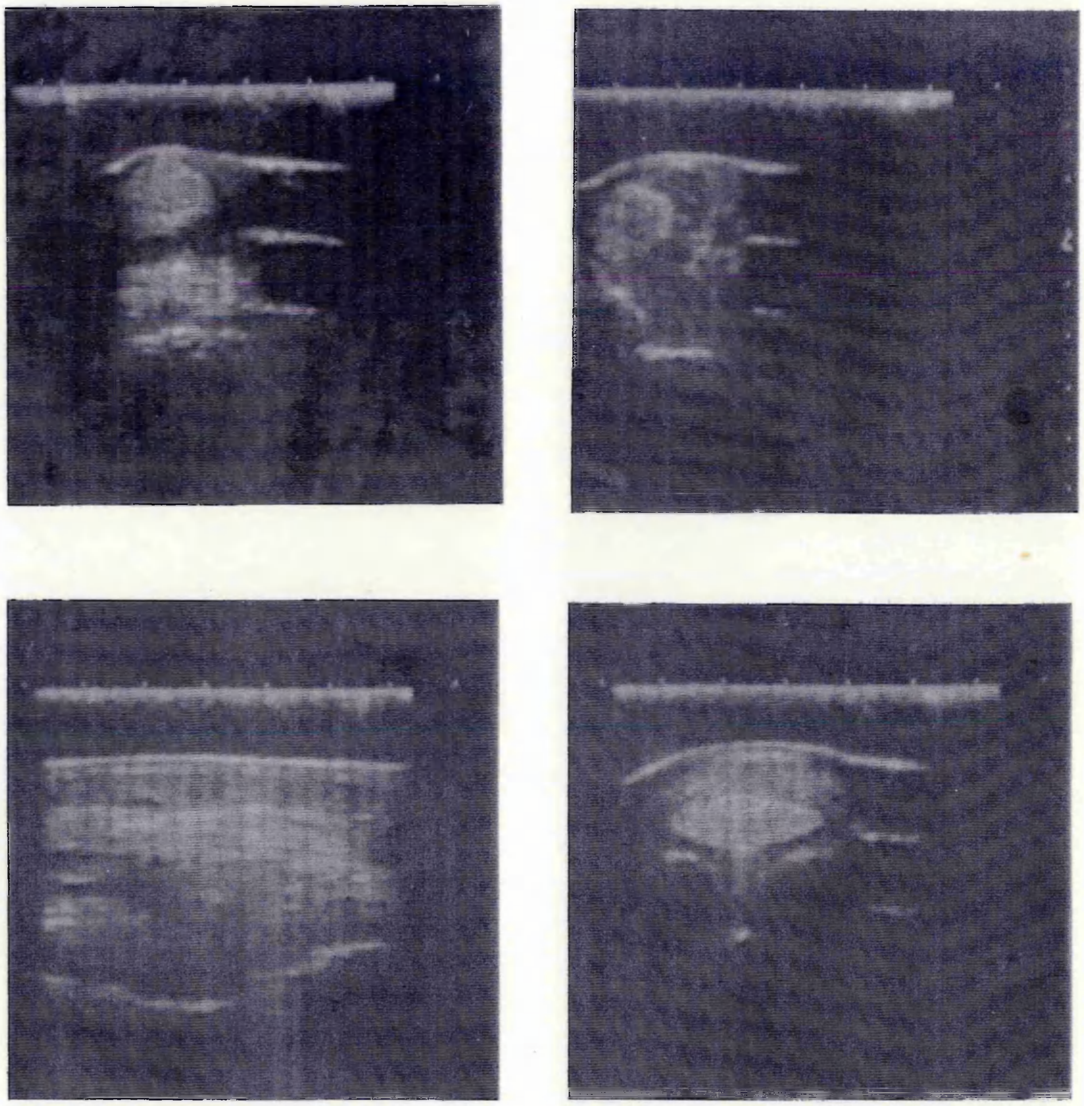
The Progression Of Ultrasonographic Findings: Echogenicity.

Table 5.1 lists the frequency of observation of each grade of echogenicity at each time-point and Figure 5.3 is a histogram which illustrates the variations in these with time. It was constructed using data collected from one examination of each horse available during each designated time period (433 ultrasonograms) and it demonstrates that there were distinct differences in the echogenicity which were dependent on the duration of the lesion. As the lesions age, the proportions of

FIG. 5.2. ULTRASONOGRAPHIC FINDINGS IN CASE 5.58.

THE SUPERFICIAL DIGITAL FLEXOR HAD COMPLETELY RUPTURED IN THE MID AND DISTAL METACARPAL REGION LEAVING AN 80 mm DEFECT. IN TRANSVERSE IMAGES OF THIS AREA THE DEEP DIGITAL FLEXOR TENDON LIES IMMEDIATELY BENEATH THE SKIN (UPPER, LEFT). ON THE MEDIAL ASPECT OF THE LIMB ANECHOIC AND HYPOECHOIC TISSUE IS PRESENT WHICH REPRESENTS THE FRAGMENTS OF SUPERFICIAL DIGITAL FLEXOR TENDON (UPPER, RIGHT).

DISTAL TO THIS POINT THE SUPERFICIAL DIGITAL FLEXOR TENDON IS LOCATED IN ITS NORMAL PALMAR POSITION BUT A HYPOECHOIC LESION FILLS ITS CENTRE (LOWER, LEFT). AT THE LEVEL OF THE METACARPOPHALANGEAL JOINT THE TENDON IS SLIGHTLY ENLARGED WITH A DIFFUSE DECREASE IN ECHOGENICITY (LOWER, RIGHT). THESE IMAGES DEMONSTRATE THAT THERE IS REMARKABLY LITTLE PERITENDINOUS SWELLING.



DURATION (weeks)	N	GRADE [number (%)] 1	2	3	4	5	NORMAL
< 4	101	43(42)	23(23)	35(35)	0	0	0
< 8	74	17(22)	18(24)	33(44)	4(4)	2(2)	0
< 16	65	7(10)	15(23)	32(49)	10(15)	20(30)	2(2)
< 26	73	2(3)	27(36)	11(15)	31(42)	46(63)	2(3)
< 36	45	0	9(20)	6(13)	28(62)	36(80)	2(4)
< 52	40	0	6(15)	4(10)	25(62)	35(87)	5(12)
< 72	29	0	8(27)	0	19(65)	22(75)	2(6)
> 72	6	0	1(16)	0	3(50)	5(83)	2(33)

N = sample size, 1 = anechoic, 2 = hypoechoic, 3 = anechoic and hypoechoic, 4 = a mixture of hypoechoic areas, 5 = hyperechoic foci.

TABLE 5.1. THE GRADES OF ECHOGENICITY IN 433 ULTRASONOGRAMS OF SUPERFICIAL DIGITAL FLEXOR TENDON LESIONS OF A VARIETY OF DURATIONS.

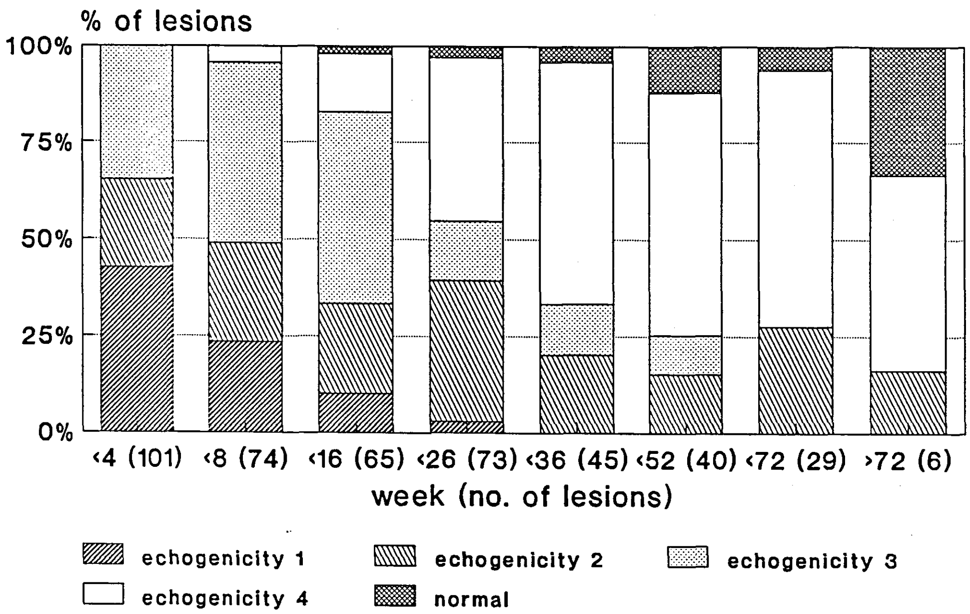


FIG. 5.3. A HISTOGRAM ILLUSTRATING THE FREQUENCY OF OBSERVATION OF THE VARIOUS GRADES OF ECHOGENICITY IN ULTRASONOGRAMS OF ACUTE AND CHRONIC SUPERFICIAL DIGITAL FLEXOR TENDON LESIONS.

anechoic and combined anechoic and hypoechoic lesions dropped. Uniform hypoechoic lesions were common in the acute stages but were also observed in chronic lesions, while the frequency of observation of mixed hypoechoic lesions increased with the duration of the lesion.

Data from 93 lesions were suitable for analysis to determine the progression of changes in echogenicity in individual animals and several distinct patterns were detected. The pattern in progression of the echogenicity as the lesions healed could be related to the severity of the initial injury, in the same way as the ultrasonographic findings in acute lesions, and Table 5.2 summarises the frequency of observation of each pattern of progression in echogenicity for mild, moderate and severe lesions.

The lesions which were initially anechoic (Fig. 5.4; echogenicity grade 1) progressed to either uniform hypoechoic areas (echogenicity grade 2) or through combinations of anechoic and hypoechoic areas (echogenicity grade 3) to combinations of (echogenicity grade 4) or uniform hypoechoic areas (echogenicity grade 2). The acute hypoechoic lesions (echogenicity grade 2) generally remained hypoechoic until they were imperceptible (Fig. 5.5). Lesions which were initially a complex mixture of anechoic and hypoechoic areas (echogenicity grade 3) progressed to complex mixtures of hypoechoic areas (echogenicity grade 4). In these cases, there was often one area which remained less echogenic than the

ECHOGENICITY	MILD	MODERATE	SEVERE
[number of lesions (% of severity subgroup)]			
1 -> 2 -> *	6 (22)	3 (12)	0
1 -> 2 -> 4	0	0	1 (2)
1 -> 3 -> 2	0	8 (33)	0
1 -> 3 -> 4	4 (14)	10 (41)	2 (5)
1 -> 4 -> 2	1 (3)	0	0
2 -> *	15 (55)	0	0
2 -> 3 -> 4	0	0	2 (5)
2 -> 4	1 (3)	2 (8)	0
3 -> 2	0	0	4 (9)
3 -> 4	0	1 (4)	23 (54)
3	0	0	4 (9)
4	0	0	6 (14)
TOTAL	27	24	41

* = normal

TABLE 5.2. THE FREQUENCY OF OBSERVATION OF EACH PATTERN OF PROGRESSION OF ECHOGENICITY IN SIXTY-FIVE HORSES WITH NINETY-TWO SUPERFICIAL DIGITAL FLEXOR TENDON INJURIES OF VARIOUS SEVERITIES.

FIG. 5.4. THE PROGRESSION OF ECHOGENICITY IN ULTRASONOGRAMS OF MODERATE SUPERFICIAL DIGITAL FLEXOR TENDON LESIONS.

ACUTE LESIONS WERE MOST FREQUENTLY ANECHOIC (ECHOGENICITY GRADE 1).

THESE EITHER PROGRESSED THROUGH GRADE 3 (MIDDLE, LEFT), ANECHOIC AND HYPOECHOIC AREAS TO GRADE 4 (LOWER, LEFT), MIXED HYPOECHOIC AREAS WITH HYPERECHOIC FOCI (GRADE 5, LEFT IMAGES) OF SLOWLY INCREASED IN ECHOGENICITY MORE UNIFORMLY THROUGH WELL-DEFINED, HYPOECHOIC GRADE 2 LESIONS (MIDDLE, RIGHT) TO ILL-DEFINED HYPOECHOIC GRADE 2 LESIONS (LOWER, RIGHT).

FIG. 5.4. THE PROGRESSION OF ECHOGENICITY IN ULTRASONOGRAMS OF MODERATE SUPERFICIAL DIGITAL FLEXOR TENDON LESIONS.

ACUTE LESIONS WERE MOST FREQUENTLY ANECHOIC (ECHOGENICITY GRADE 1, UPPER LEFT AND RIGHT).

THESE EITHER PROGRESSED THROUGH GRADE 3 (MIDDLE, LEFT), ANECHOIC AND HYPOECHOIC AREAS TO GRADE 4 (LOWER, LEFT), MIXED HYPOECHOIC AREAS WITH HYPERECHOIC FOCI (GRADE 5, LEFT IMAGES) OF SLOWLY INCREASED IN ECHOGENICITY MORE UNIFORMLY THROUGH WELL-DEFINED, HYPOECHOIC GRADE 2 LESIONS (MIDDLE, RIGHT) TO ILL-DEFINED HYPOECHOIC GRADE 2 LESIONS (LOWER, RIGHT).

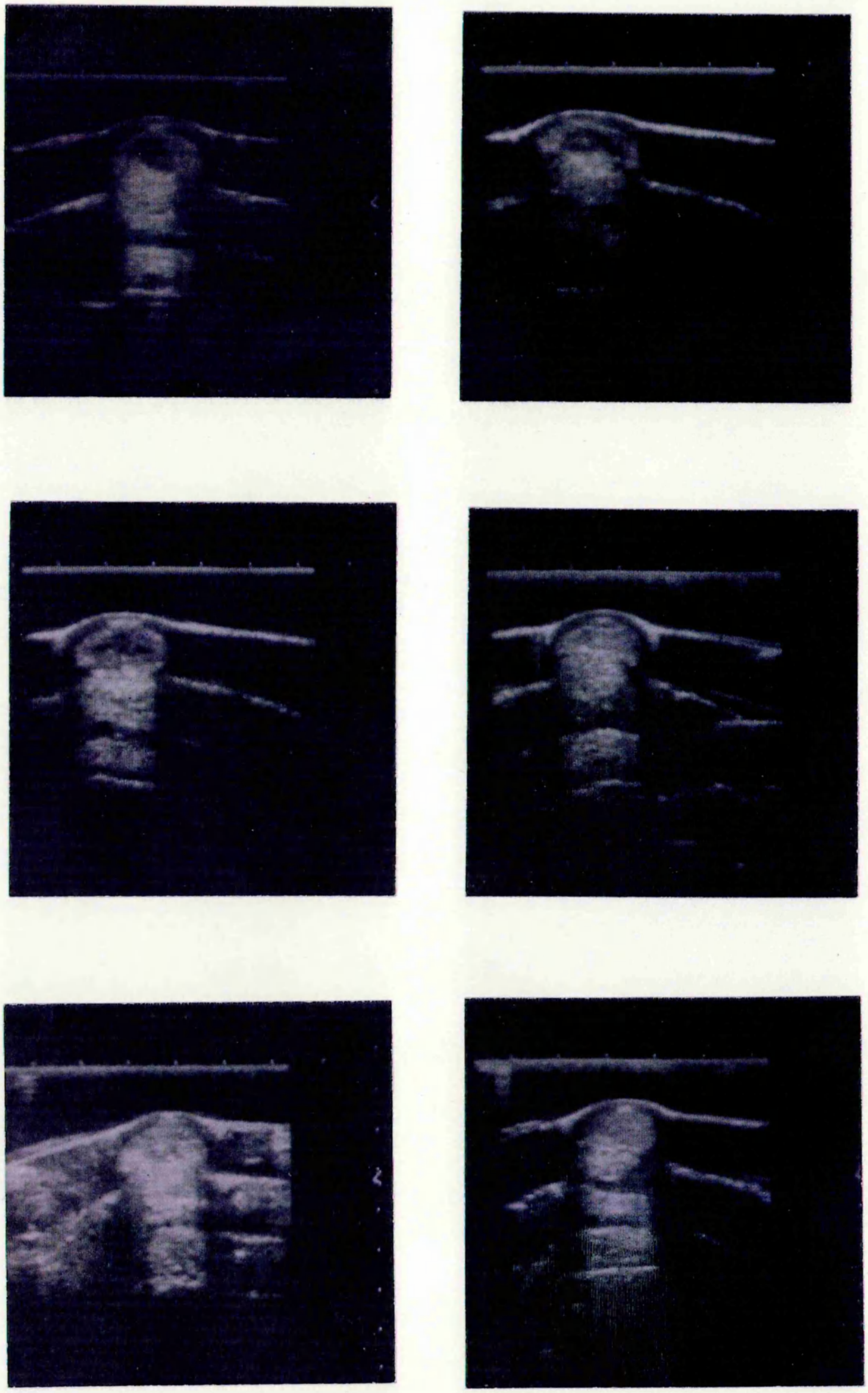
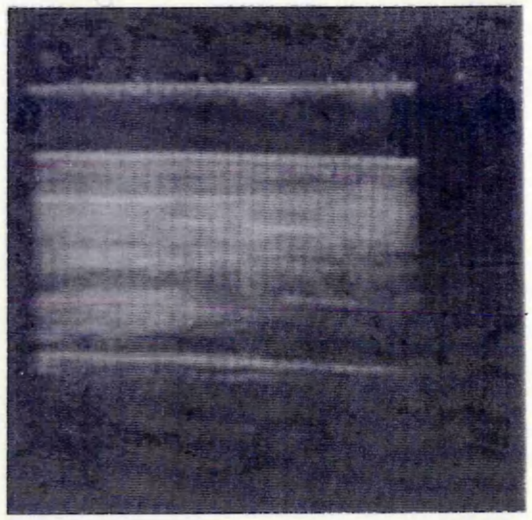
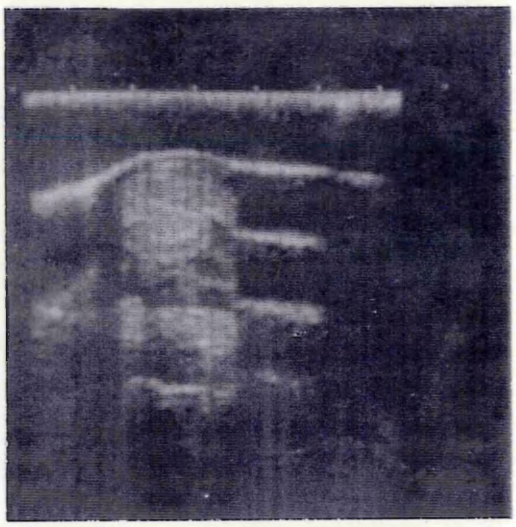
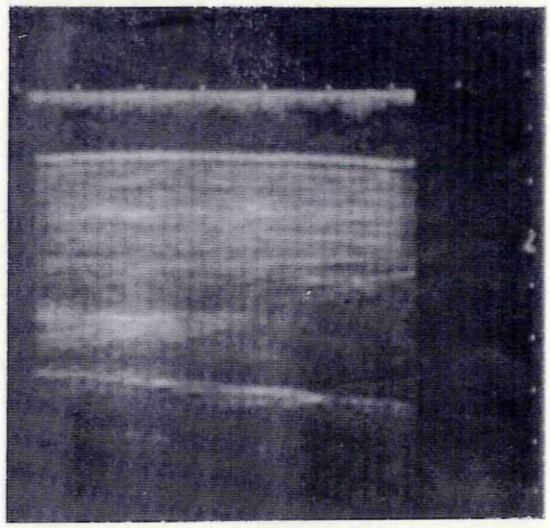


FIG. 5.5. THE PROGRESSION OF MILD SUPERFICIAL DIGITAL FLEXOR TENDON LESIONS.

SMALL, WELL-DEFINED HYPOECHOIC LESIONS (ECHOGENICITY GRADE 2, LESION BORDER GRADE 4, UPPER, LEFT AND RIGHT) BECAME ILL-DEFINED WITH NORMAL ECHOGENICITY AND REGULAR LINEAR ECHO ARRANGEMENT IN FIVE TO NINE MONTHS (LESION BORDER GRADE 1, LINEAR ECHO GRADE 4, LOWER, LEFT AND RIGHT).

rest of the lesion for considerable periods of time and these areas were most frequently detected in the distal third of the metacarpal region of the tendon with similar areas being observed occasionally in the middle third but not in the proximal third (Fig. 5.6).

Small hyperechoic foci within the lesions were a feature of chronic injuries and these ranged in size within individuals from pinpoints to several millimetres in diameter (Figs. 5.4 and 5.7).

Cases 5.23 and 5.35 were atypical but similar: the lesions were diffusely hypoechoic throughout the entire superficial digital flexor tendon in the acute stages and between weeks four to twelve both anechoic and hyperechoic areas appeared within the tendon (Figs. 5.8 and 5.9). The hyperechoic areas were extremely dramatic, large, irregular aggregations which were unlike the hyperechoic foci described above. One horse (Case 5.42), had a hypoechoic lesion on week one which was subsequently found to be anechoic on weeks four and twelve.

The Progression Of Ultrasonographic Findings: Lesion Border And Linear Echo Formation.

In all cases, the distinctness of the lesion border and the linear echo formation also progressed gradually as the lesions began to heal and Figures 5.10 and 5.11 and Tables 5.3 and 5.4 illustrate the frequency of observation of each grade of lesion border and linear echo formation at each time point.

FIG. 5.6. WELL-DEFINED HYPOECHOIC AREAS WITHIN CHRONIC LESION.

IN MANY CASES, WELL-DEFINED HYPOECHOIC AREAS WERE PRESENT IN LESIONS FOR LONG PERIODS OF TIME. IN MOST CASES THESE WERE LOCATED IN THE DISTAL OR MID METACARPAL REGIONS.

IN CASE 5.16 A HYPOECHOIC AREA WAS PRESENT IN THE DISTAL THIRD AT 52 WEEKS (UPPER).

IN CASE 5.4 A HYPOECHOIC AREA REMAINED IN THE DISTAL THIRD OF THE METACARPAL REGION UNTIL 74 WEEKS AFTER THE INITIAL INJURY (LOWER IMAGE, 68 WEEKS).

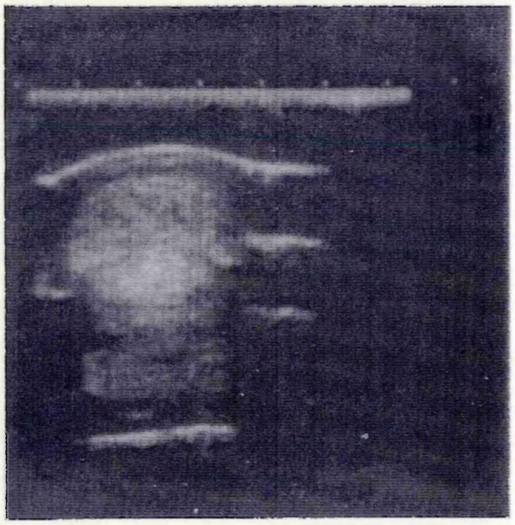
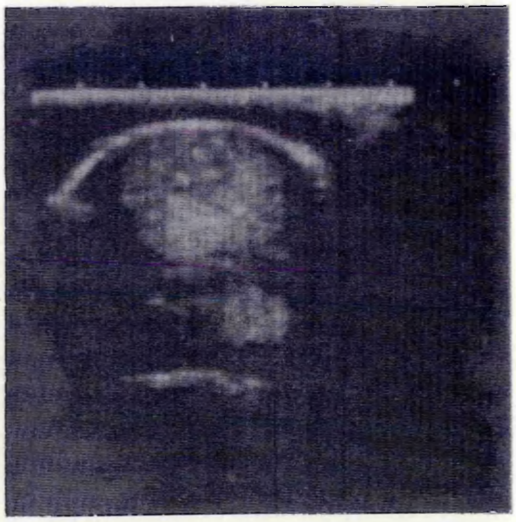
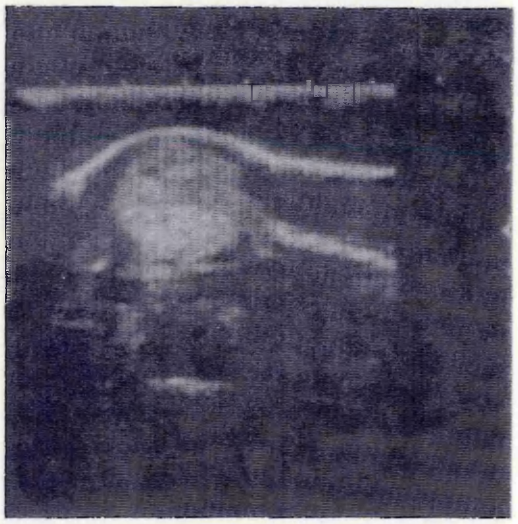


FIG. 5.7. EXAMPLES OF HYPERECHOIC FOCI (ECHOGENICITY GRADE 5) WITHIN CHRONIC SUPERFICIAL DIGITAL FLEXOR TENDON LESIONS.

HYPERECHOIC FOCI RANGED IN SIZE FROM PINPOINTS (UPPER) TO SEVERAL MILLIMETRES IN DIAMETER (MIDDLE). BOTH PINPOINT AND LARGER HYPERECHOGENICITIES WERE OBSERVED WITHIN THE SAME INDIVIDUALS (LOWER).

[NOTE: THERE IS AN OFF-NORMAL INCIDENCE ARTIFACT IN THE DEEP DIGITAL FLEXOR TENDON IN THE UPPER IMAGE].





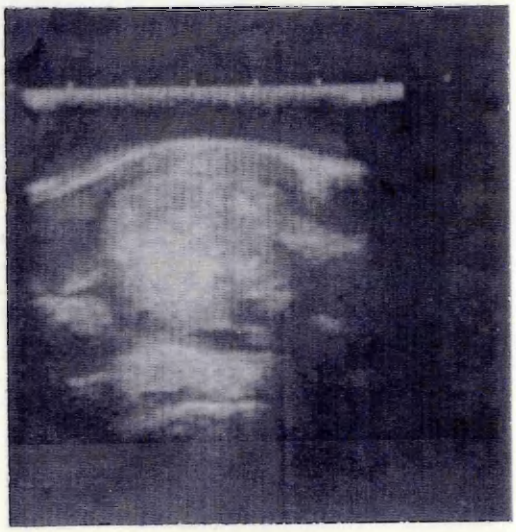


FIG. 5.8. ULTRASONOGRAPHIC FINDINGS IN CASE 5.23.

THIS HORSE WAS ATYPICAL: THE INITIAL DIFFUSE DECREASE IN ECHOGENICITY WAS REPLACED WITH LARGE ANECHOIC FOCI (UPPER, LEFT) AND AGGREGATIONS OF EXTREMELY ECHOGENIC MATERIAL (UPPER, RIGHT) IN EXAMINATIONS AT FOUR, EIGHT AND TWELVE WEEKS DURATION. THEREAFTER, THE LESION BEGAN TO BE LESS DISTINCT ALTHOUGH A WELL-DEFINED HYPOECHOIC AREA WAS APPARENT IN THE DISTAL THIRD OF THE METACARPAL REGION (LOWER, LEFT AND RIGHT) ON EXAMINATIONS AT TWENTY-SIX TO SIXTY-FOUR WEEKS' DURATION. HYPERECHOIC AREAS REMAINED (LOWER, RIGHT) BUT THESE WERE TYPICAL HYPERECHOIC FOCI ASSOCIATED WITH SCAR FORMATION.

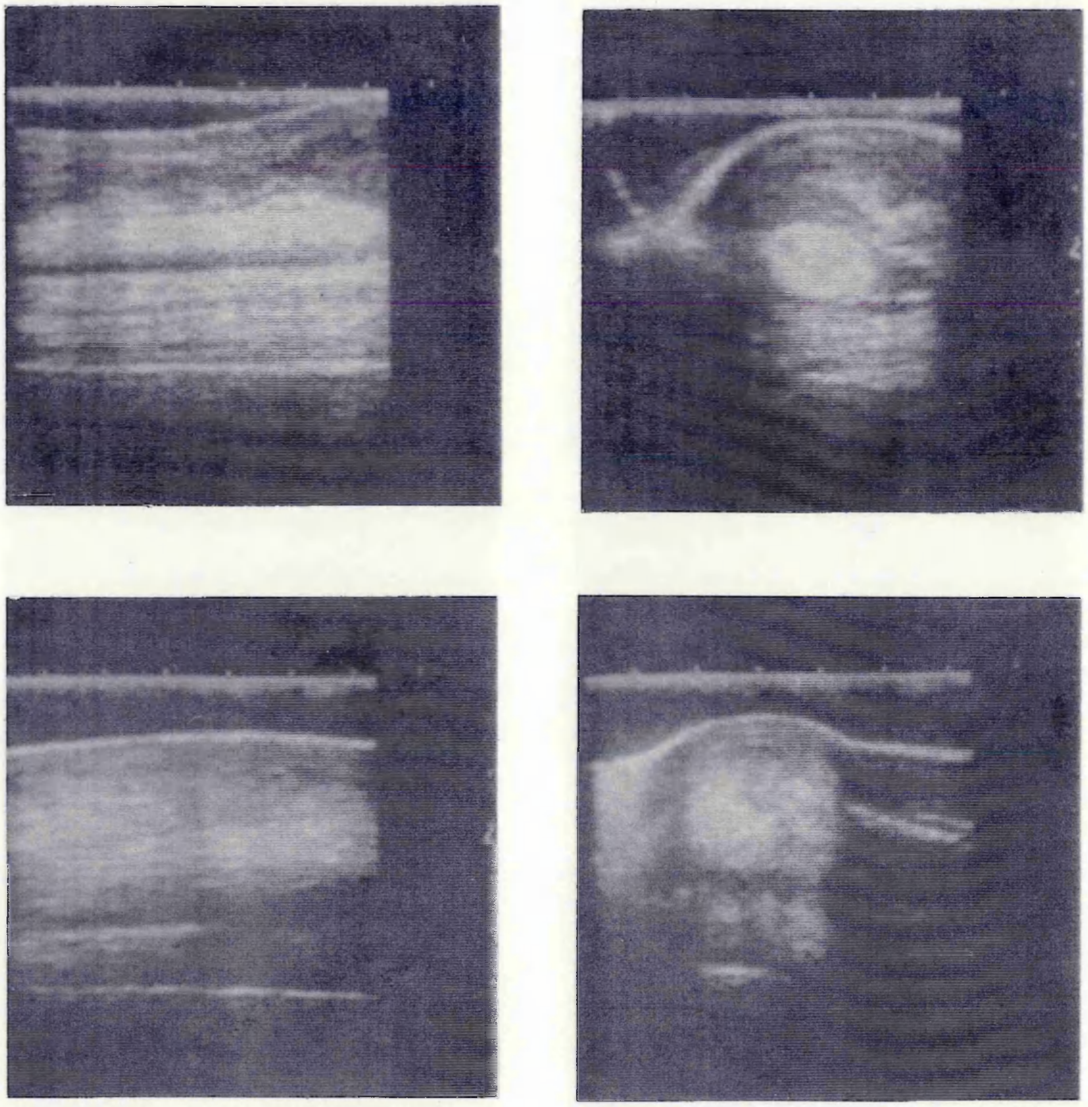


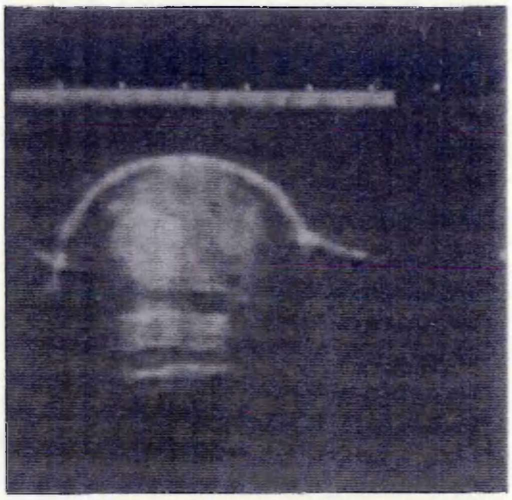
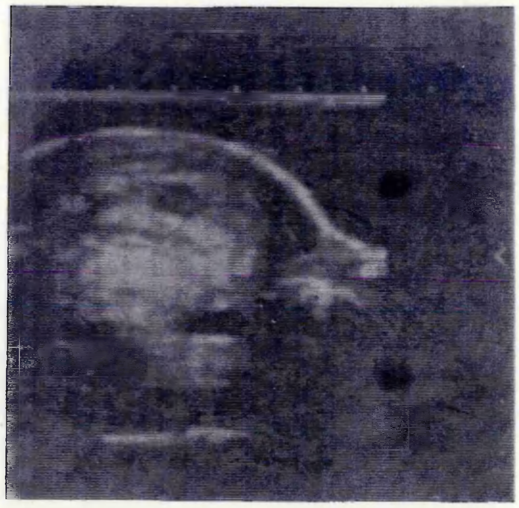
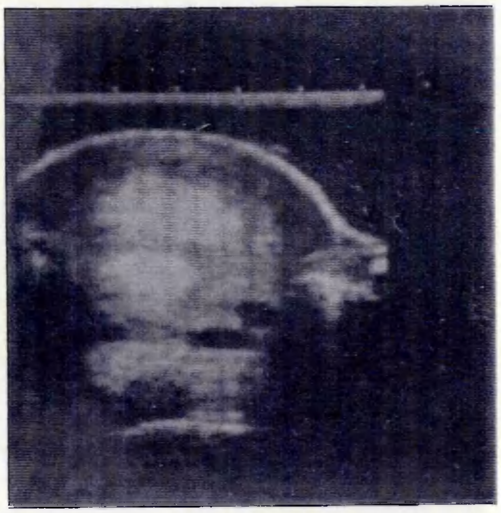
FIG. 5.9. ULTRASONOGRAPHIC FINDINGS IN CASE 5.35.

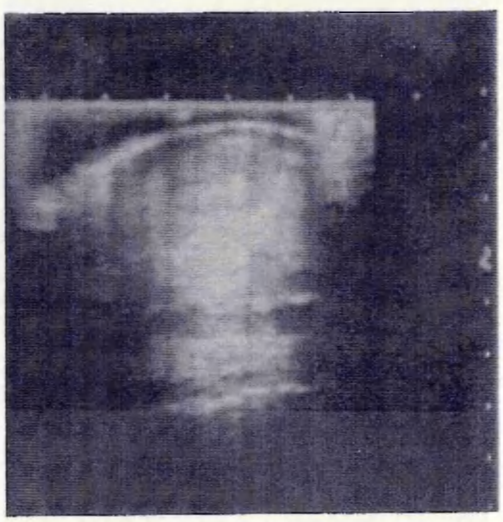
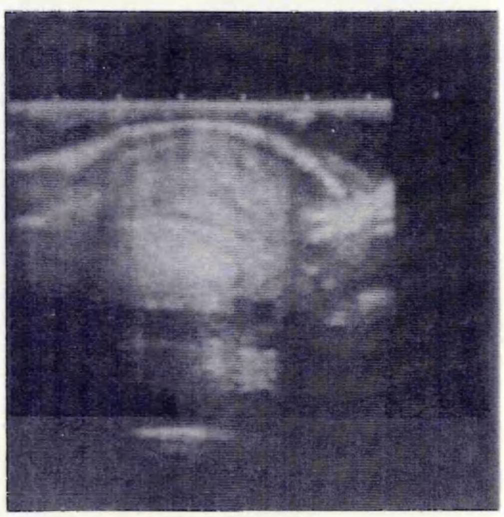
THIS HORSE WAS ATYPICAL: THE INITIAL ULTRASONOGRAPHIC FINDINGS (2 DAYS POST INJURY) WERE A DIFFUSE DECREASE IN ECHOGENICITY THROUGHOUT THE ENTIRE WIDTH AND LENGTH OF THE SUPERFICIAL DIGITAL FLEXOR TENDON WITH SMALL ANECHOIC FOCI SEEN OCCASIONALLY (UPPER, LEFT). EXAMINATIONS WERE PERFORMED ON WEEKS 2 AND 3 IN WHICH THESE FINDINGS WERE UNCHANGED.

ULTRASONOGRAPHIC EXAMINATION ON WEEK FOUR DEMONSTRATED THAT LARGE HYPERECHOIC AREAS HAD FORMED (MIDDLE, LEFT AND RIGHT) AND THESE WERE INTERSPERSED WITH ANECHOIC AREAS (UPPER, RIGHT).

ON WEEK EIGHT, THE OVERALL ECHOGENICITY OF THE TENDON HAD INCREASED AND THESE HYPERECHOIC AREAS WERE STILL PRESENT AND THEY WERE OUTLINED BY HYPOECHOIC RIMS (LOWER, LEFT AND RIGHT).

[NOTE: THERE IS INCOMPLETE CONTACT ON THE LATERAL ASPECT OF THE UPPER, RIGHT, THE MIDDLE LEFT AND RIGHT AND THE LOWER RIGHT IMAGES AND ON THE MEDIAL ASPECT OF THE LOWER LEFT IMAGE.

DURATION (weeks)	N	GRADE [number (%)] 0	1	2	3	4
< 4	101	21 (20)	0	0	22 (21)	58 (57)
< 8	74	19 (25)	1 (1)	3 (4)	21 (28)	26 (35)
< 16	65	23 (35)	3 (4)	7 (10)	26 (40)	6 (9)
< 26	73	27 (36)	7 (9)	34 (46)	5 (6)	0
< 36	45	17 (37)	14 (31)	5 (11)	9 (20)	0
< 52	40	23 (57)	11 (27)	0	5 (12)	1 (2)
< 72	29	22 (75)	2 (6)	2 (6)	3 (10)	0
> 72	6	4 (66)	1 (16)	1 (16)	0	0

N = sample size, * = could not be discerned, 1 = difficult to discern, 2 = moderately difficult to discern, 3 = distinct, 4 = very distinct.

TABLE 5.3. THE GRADES OF LESION BORDER IN 433 ULTRASONOGRAMS OF SUPERFICIAL DIGITAL FLEXOR TENDON LESIONS OF A VARIETY OF DURATIONS.

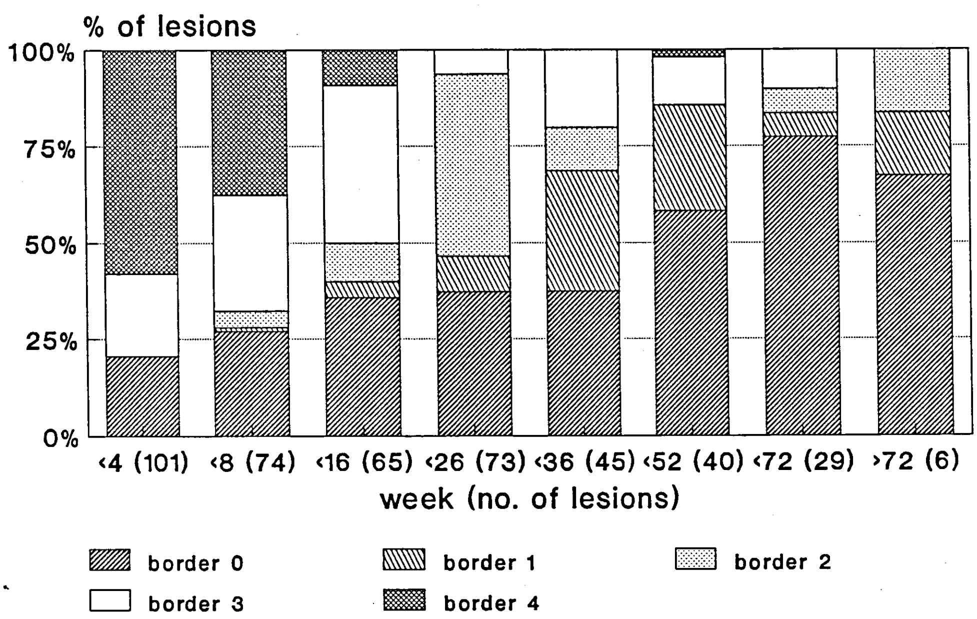


FIG. 5.10. A HISTOGRAM ILLUSTRATING THE FREQUENCY OF OBSER TION OF THE VARIOUS GRADES OF LESION BORDER ULTRASONOGRAMS OF ACUTE AND CHRONIC SUPERFICIAL DIGI FLEXOR TENDON LESIONS.

DURATION (weeks)	N	GRADE [number (%)] 0	1	2	3	4
< 4	101	92 (91)	0	9 (9)	0	0
< 8	74	53 (71)	10 (13)	10 (13)	1 (1)	0
< 16	65	21 (32)	32 (49)	6 (9)	6 (9)	0
< 26	73	0	17 (23)	30 (41)	16 (21)	10 (13)
< 36	45	1 (2)	3 (6)	27 (60)	11 (24)	3 (6)
< 52	40	0	1 (2)	15 (37)	18 (45)	6 (15)
< 72	29	0	0	4 (13)	15 (51)	10 (34)
> 72	6	0	0	0	4 (66)	2 (33)

N = sample size, 0 = absent, 1 = very short echoes, 2 = some linear echoes present, 3 = some long but irregular linear echoes present, 4 = linear echoes which are slightly irregular present.

TABLE 5.4. THE GRADES OF LINEAR ECHOES IN 433 ULTRASONOGRAMS OF SUPERFICIAL DIGITAL FLEXOR TENDON LESIONS OF A VARIETY OF DURATIONS.

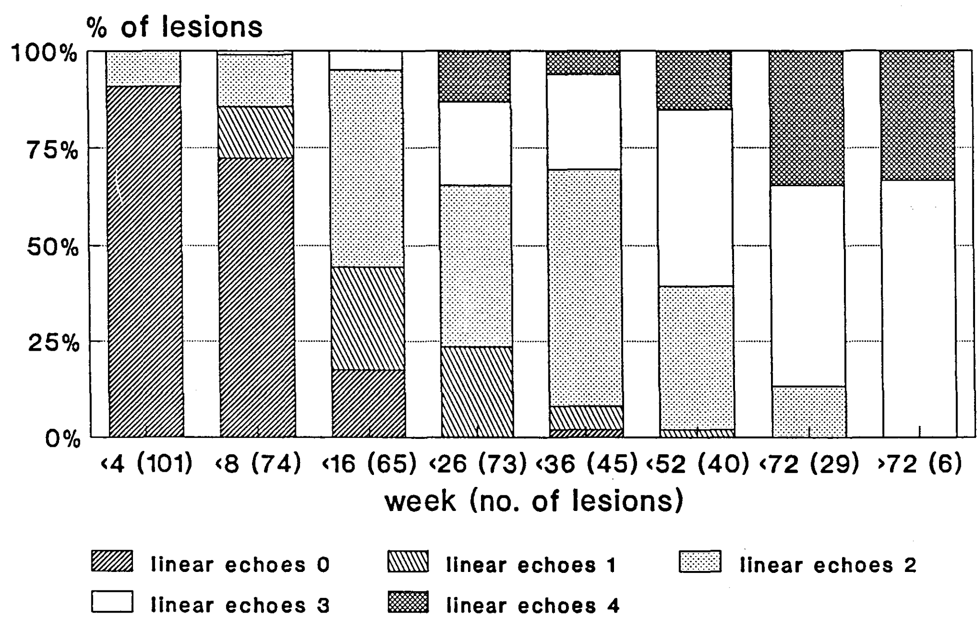


FIG. 5.11. A HISTOGRAM ILLUSTRATING THE FREQUENCY OF OBSERVATION OF THE VARIOUS GRADES OF DISTINCTNESS OF LINEAR ECHO FORMATION IN ULTRASONOGRAMS OF ACUTE AND CHRONIC SUPERFICIAL DIGITAL FLEXOR TENDON LESIONS.

The lesion borders were most obvious in the acute stages and became progressively less easy to define (Fig. 5.12), while the number of linear echoes and their length and regularity increased with time (Fig. 5.13).

Assessment Of The Peritendinous Structures.

Three separate peritendinous abnormalities were detected on ultrasonographic examination. In a number of acute cases distinct anechoic areas were present between the skin and the superficial digital flexor tendon (Fig. 5.14). Such areas tended to disappear within the first four weeks of injury. In some chronic lesions, distinct hypoechoic bands appeared between the superficial digital flexor tendon and the skin and these were confined to the mid and distal thirds of the metacarpal area. The boundary of between the deep and superficial digital flexor tendon was frequently indistinct but this parameter was felt to be extremely subjective.

Factors Influencing The Severity of Superficial Digital Flexor Tendon Injury.

The severity of superficial digital flexor tendon injury was determined on the initial examination and this assessment was based principally on the size of the lesion but, as is indicated above, the echogenicity was also dependent on the severity and was an additional factor which could be used to evaluate severity (Fig. 5.15).

A reliable history of the occurrence of previous superficial digital flexor tendon injury was obtained in 47 cases. Sixteen horses with severe lesions

FIG. 5.12. THE PROGRESSION OF LESION BORDER DISTINCTNESS IN ULTRASONOGRAMS OF SUPERFICIAL DIGITAL FLEXOR TENDON LESIONS.

GRADE 4: IN SUPERFICIAL DIGITAL FLEXOR TENDON LESIONS IN WHICH A BOUNDARY WAS APPARENT IN THE ACUTE STAGES (ALL BUT THE MOST SEVERE), THIS WAS EXTREMELY DISTINCT IN BOTH MILD (UPPER, LEFT) AND MORE SEVERE LESIONS (UPPER, RIGHT).

GRADE 3: AS THE LESIONS AGED THE BOUNDARY REMAINED OBVIOUS BUT IT BEGAN TO LOOSE ITS DISTINCT EDGES AS THE ECHOGENICITY OF THE LESIONS INCREASED (MIDDLE, LEFT).

GRADE 2: IN CHRONIC LESIONS, THE ECHOGENICITY OF THE LESION WAS GENERALLY REDUCED BUT THE PRECISE BOUNDARY BECAME MORE DIFFICULT TO DISCERN (MIDDLE, RIGHT).

GRADE 1: A ILL-DEFINED CENTRAL REDUCTION IN ECHOGENICITY WAS APPARENT BUT IT BLENDS WITH THE SURROUNDING TENDON PARTICULARLY ON THE MEDIAL ASPECT (LOWER, LEFT).

IN THE LOWER, RIGHT IMAGE A LESION BOUNDARY COULD NOT BE DISCERNED ALTHOUGH THE ECHOGENICITY IS NOT COMPLETELY HOMOGENOUS THROUGHOUT THE TENDON.

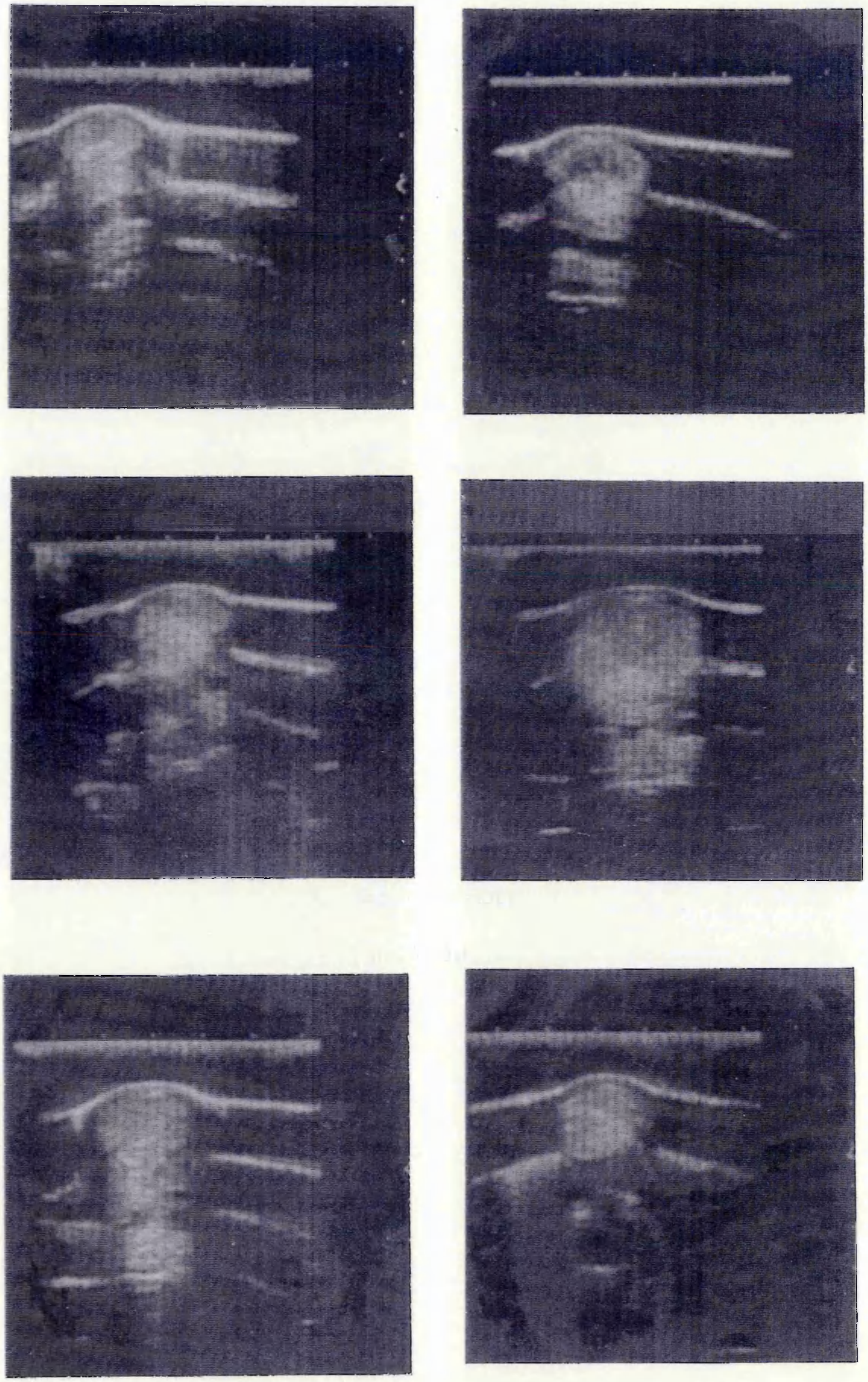


FIG. 5.13. THE PROGRESSION OF LINEAR ECHO FORMATION WITH THE DURATION OF THE LESION IN SUPERFICIAL DIGITAL FLEXOR TENDON INJURY.

GRADE 0: IN ACUTE LESIONS THERE ARE NO LINEAR ECHOES AND THE LESION IS PREDOMINANTLY ANECHOIC (UPPER, LEFT).

GRADE 1: THE LESION INITIALLY FILLS IN WITH IRREGULAR, SHORT ECHOGENICITIES WHICH ARE IRREGULARLY ARRANGED (UPPER, RIGHT).

GRADE 2: THIS PROGRESSES TO A MORE UNIFORM PATTERN IN WHICH LINEAR ECHOES ARE PRESENT BUT THEY ARE SHORT (MIDDLE, LEFT).

GRADE 3: LONGER LINEAR ECHOES BEGIN TO APPEAR (MIDDLE RIGHT).

GRADE 4: ULTIMATELY, NUMEROUS LONGER, LINEAR ECHOES ARE PRESENT BUT THEIR ARRANGEMENT IS NOT UNIFORM (LOWER).

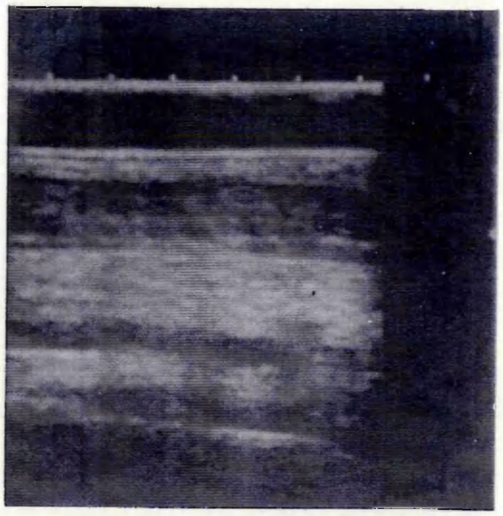
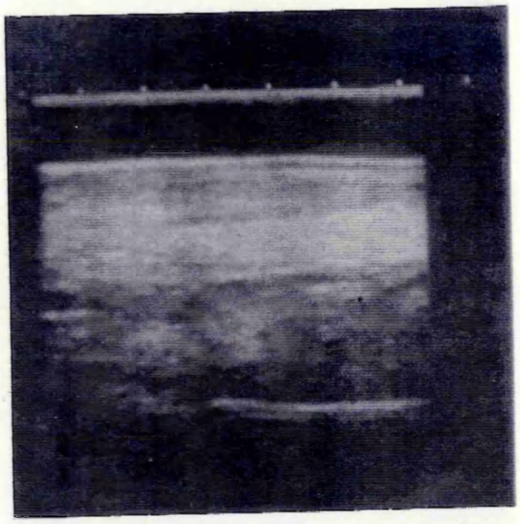
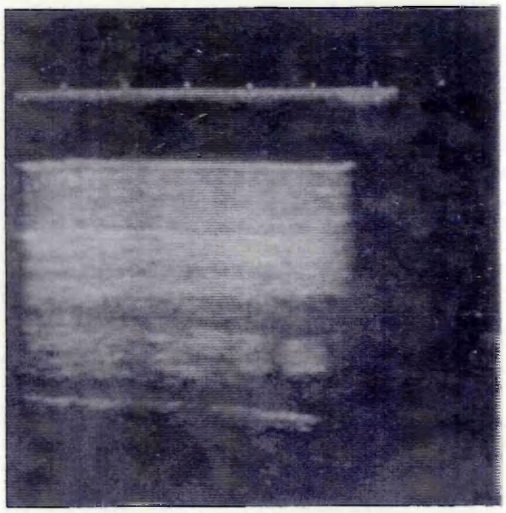
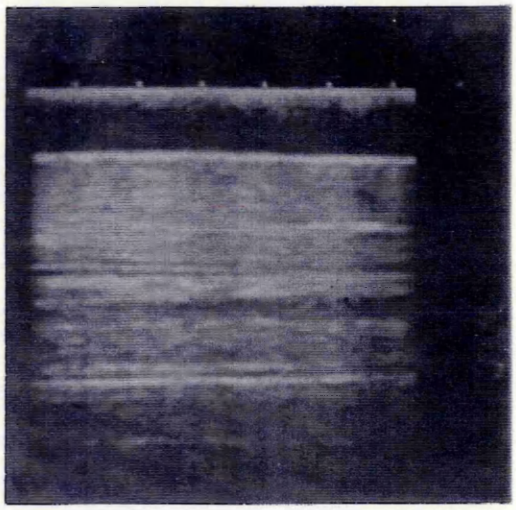
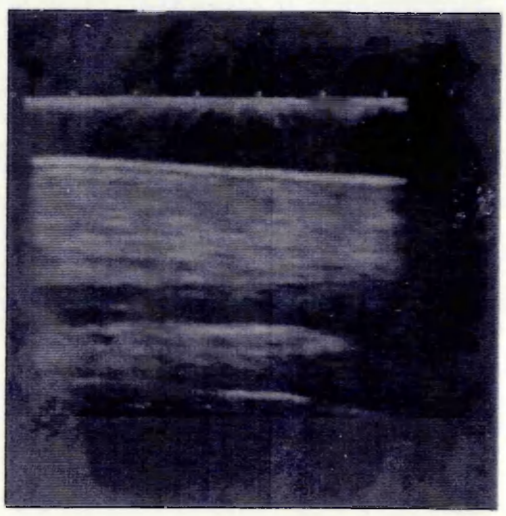
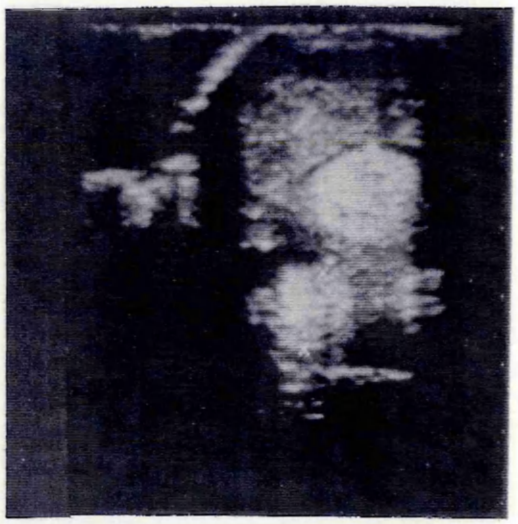
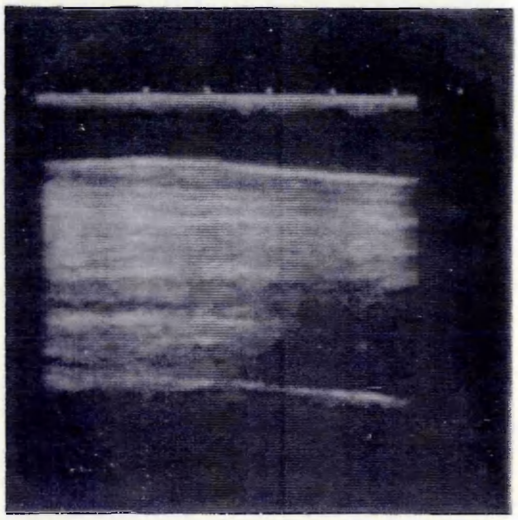






FIG. 5.14. THE ULTRASONOGRAPHIC APPEARANCE OF PERITENDINOUS LESIONS ASSOCIATED WITH ACUTE FLEXOR TENDON INJURY.

AN ANECHOIC AREA LAY BETWEEN THE PALMAR ASPECT OF THE SUPERFICIAL DIGITAL FLEXOR TENDON AND THE SKIN IN A HORSE WITH A LARGE SUPERFICIAL DIGITAL FLEXOR TENDON INJURY WHICH COMPRISED THE ENTIRE CROSS-SECTIONAL AREA (CASE 5.29, UPPER).

A BAND OF HYPOECHOIC TISSUE LAY BETWEEN THE PALMAR ASPECT OF THE SUPERFICIAL DIGITAL FLEXOR TENDON AND THE SKIN IN A HORSE WITH A MILD SUPERFICIAL DIGITAL FLEXOR TENDON INJURY (CASE 5.34, MIDDLE AND LOWER). THIS IS MOST OBVIOUS IN THE LONGITUDINAL IMAGE (MIDDLE) IN WHICH THE TENDON LESION IS NOT APPARENT BECAUSE THIS IMAGE WAS OBTAINED FROM THE MOST MEDIAL ASPECT OF THE TENDON. IN THE TRANSVERSE IMAGE, THE PERITENDINOUS LESION IS NOT AS OBVIOUS (LOWER) BUT A WELL-DEFINED HYPOECHOIC AREA (ECHOGENICITY GRADE 2) IS PRESENT IN THE CENTRAL AND LATERAL ZONE OF THE SUPERFICIAL DIGITAL FLEXOR TENDON.





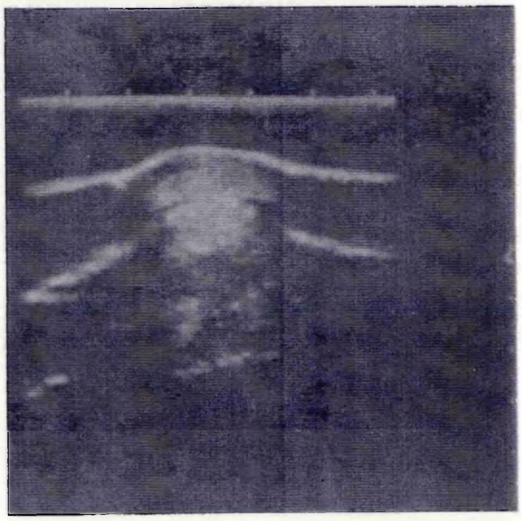


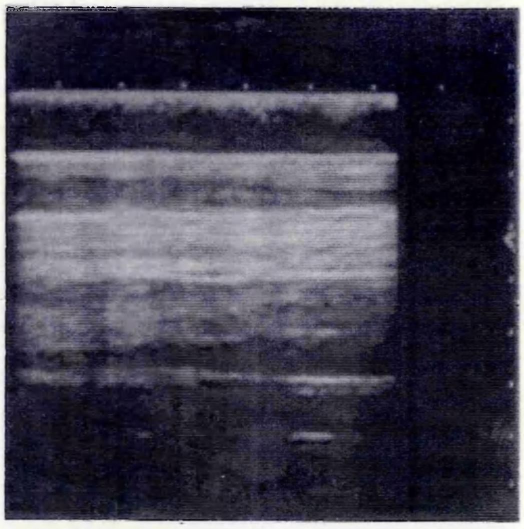
FIG. 5.15. GRADING THE SEVERITY OF SUPERFICIAL DIGITAL FLEXOR TENDON LESIONS BY ULTRASONOGRAPHIC EXAMINATION.

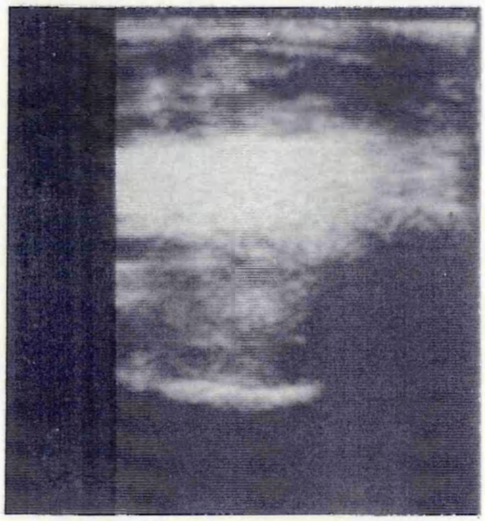
THE SEVERITY OF THE ACUTE SUPERFICIAL DIGITAL FLEXOR TENDON LESIONS WAS DETERMINED BY ASSESSING THE ECHOGENICITY AND THE SIZE OF THE LESION AND DETERMINING THE PROPORTION OF THE CROSS SECTIONAL AREA OF THE TENDON AFFECTED.

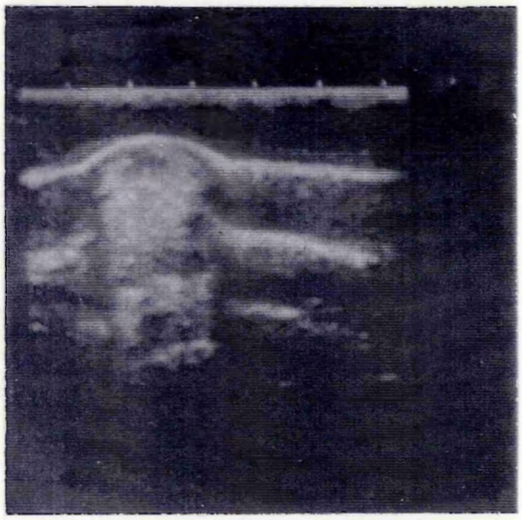
THE MODERATELY SEVERE LESION IN THE UPPER LEFT AND RIGHT IMAGES IS LOCATED IN THE CENTRAL ZONE OF THE MIDDLE THIRD OF THE TENDON AND COMPRISES APPROXIMATELY 60 % OF THE CROSS-SECTIONAL AREA OF THE TENDON AT THAT POINT. ITS ECHOGENICITY IS UNIFORMLY ANECHOIC (ECHOGENICITY GRADE 1).

THE SEVERE LESION IN THE LOWER LEFT IMAGE EXTENDS THROUGHOUT THE METACARPAL REGION (THE DISTAL THIRD IS DEPICTED) AND ITS ECHOGENICITY IS AN IRREGULAR COMBINATION OF ANECHOIC AND HYPOECHOIC AREAS (ECHOGENICITY GRADE 3).

THE MILD LESION IN THE LOWER RIGHT IMAGE, IS HYPOECHOIC (ECHOGENICITY GRADE 2) AND IT COMPRISES APPROXIMATELY 30 % OF THE CROSS-SECTIONAL AREA OF THE TENDON.







had experienced a previous incident of superficial digital flexor tendon injury (76%) whereas five sustained a severe injury as an initial lesion (23%). The history was known in 13 cases with moderate lesions and 13 cases with mild lesions and, in both these groups, two horses (15%) had previously been diagnosed as having a superficial digital flexor tendon injury. Previous injury had a highly significant effect on the severity of the lesion ($p < 0.005$).

The influence of age on severity of superficial digital flexor injury is demonstrated in Table 5.5. Although the mean ages for each group were similar (unilateral mild, 5.8 years; bilateral mild, 6 years; unilateral moderate, 6.07 years, bilateral moderate, 6.5 years, unilateral severe, 6.8; bilateral severe, 6.3), comparison of the distribution of severity within the age groups demonstrated that there was a lower incidence of mild lesions within the older horses. However, the differences between the groups were not statistically different. Equally, there was no significant difference between the severity of lesions in males and females.

Factors Influencing The Eventual Outcome In Superficial Digital Flexor Tendon Injury In The Horse.

The age, the history and the treatment regimen of the animal did not influence the ability to return to work, the lay-off period or the recurrence rate and there were no significant differences in the distribution of the end points in any of these subgroups (Table 5.6). The

SEVERITY OF SDFT LESION	AGE (years) [number of horses (% of age subgroup)] < OR = 5		6 + 7		> OR = 8	
MILD UNILAT	8	(26)	7	(16)	2	(11)
MILD BILAT	0		3	(7)	0	
MODERATE UNILAT	5	(16)	6	(14)	2	(11)
MODERATE BILAT	3	(10)	8	(19)	1	(5)
SEVERE UNILAT	8	(26)	6	(14)	10	(55)
SEVERE BILAT	6	(21)	12	(23)	3	(16)
TOTAL	30		42		18	

SDFT = superficial digital flexor tendon
MILD UNILAT = unilateral mild lesion
MILD BILAT = bilateral mild lesions
MODERATE OR SEVERE UNILAT = moderate or severe unilateral lesion
MODERATE BILAT = bilateral lesions, the most severe of which is moderate
SEVERE BILAT = bilateral lesions, the most severe of which is severe

TABLE 5.5. THE INFLUENCE OF AGE ON THE SEVERITY OF SUPERFICIAL DIGITAL FLEXOR TENDON INJURY IN NINETY HORSES.

TABLE 5.6. THE OUTCOME AND RECURRENCE RATE AFTER AT LEAST NINE MONTHS IN 90 HORSES WITH SUPERFICIAL DIGITAL FLEXOR TENDON INJURY.

N = total sample size
N1 = number with unknown outcome
N2 = number with known outcome
RACE = raced
TRAIN = trained
WORK = either raced of trained
RECD = recurred
LAY-OFF (mths) = period of rest prior to starting work in months
ALL MILD = bilateral injuries which were both mild
ALL MODERATE = bilateral injuries the most severe of which was moderate
ALL SEVERE = bilateral injuries the most severe of which was severe.

TABLE 5.6. THE OUTCOME AND RECURRENCE RATE AFTER AT LEAST NINE MONTHS IN 90 HORSES WITH SUPERFICIAL DIGITAL FLEXOR TENDON INJURY.

N = total sample size
N1 = number with unknown outcome
N2 = number with known outcome
RACE = raced
TRAIN = trained
WORK = either raced or trained
RECD = recurred
LAY-OFF (mths) = period of rest prior to starting work in months
ALL MILD = bilateral injuries which were both mild
ALL MODERATE = bilateral injuries the most severe of which was moderate
ALL SEVERE = bilateral injuries the most severe of which was severe.

N	N1	N2	RACE	TRAIN	WORK	RECD	RETIRED
				number (%)			
			LAY OFF [mean (range), mths]				
ALL ANIMALS							
90	21	69	19 (27)	10 (14)	29 (42)	10 (35)	40 (58)
				13.5 (6 - 26)			
UNILATERAL MILD							
17	9	8	5 (62)	3 (37)	8 (100)	2 (25)	0
				8.8 (7 - 11)			
ALL MILD							
20	11	9	6 (66)	3 (33)	9 (100)	2 (22)	0
				9.2 (6 - 12)			
UNILATERAL MODERATE							
13	7	6	2 (33)	2 (33)	4 (66)	2 (40)	2 (33)
				10.8 (9 - 12)			
ALL MODERATE							
25	7	18	4 (22)	3 (16)	7 (38)	4 (57)	11 (61)
				11.25 (6 - 18)			
UNILATERAL SEVERE							
24	5	19	3 (15)	1 (5)	4 (20)	0	15 (80)
				21.5 (12 - 26)			
ALL SEVERE							
45	5	40	9 (22)	3 (7)	12 (30)	4 (36)	28 (70)
				18.9 (9 - 26)			
MARES							
24	7	17	2 (11)	1 (5)	3 (17)	2 (66)	14 (82)
				17 (7 - 26)			
GELDINGS							
66	14	52	17 (32)	9 (17)	26 (50)	8 (30)	26 (50)
				13 (6 - 24)			
AGE = < or = 5 y.o.							
30	8	22	9 (40)	1 (4)	10 (44)	3 (30)	12 (54)
				12.4 (8 - 24)			
AGE = 6 - 7 y.o.							
42	8	34	7 (20)	7 (20)	14 (40)	3 (21)	20 (58)
				10.8 (6 - 18)			
AGE = > OR = 8 y.o.							
18	7	11	3 (27)	2 (18)	5 (54)	2 (40)	6 (54)
				13.2 (9 - 24)			
PREVIOUS INJURY							
21	3	18	8 (44)	1 (5)	9 (50)	2 (22)	9 (50)
				12.3 (8 - 24)			
NO PREVIOUS INJURY							
18	5	13	4 (30)	6 (46)	10 (76)	3 (30)	3 (23)
				10.6 (6 - 12)			
TREATMENT = CONSERVATIVE							
54	13	41	15 (36)	4 (9)	19 (47)	6 (19)	21 (51)
				13.6 (6 - 24)			
TREATMENT = POLYSULPHATED GLYCOSAMINOGLYCANS							
17	7	10	2 (20)	5 (50)	7 (70)	3 (42)	3 (30)
				9.5 (7 - 10)			
TREATMENT = THERAPEUTIC LASER							
10	3	7	2 (28)	1 (14)	3 (42)	0	4 (57)
				15.6 (9 - 26)			

sex of the animal did influence the numbers returning to work with a greater number of mares than geldings being retired (Table 5.6; $p < 0.05$). However, for those mares that did return to work, there was no significant difference in the duration of the lay-off period or the recurrence rate when compared to geldings.

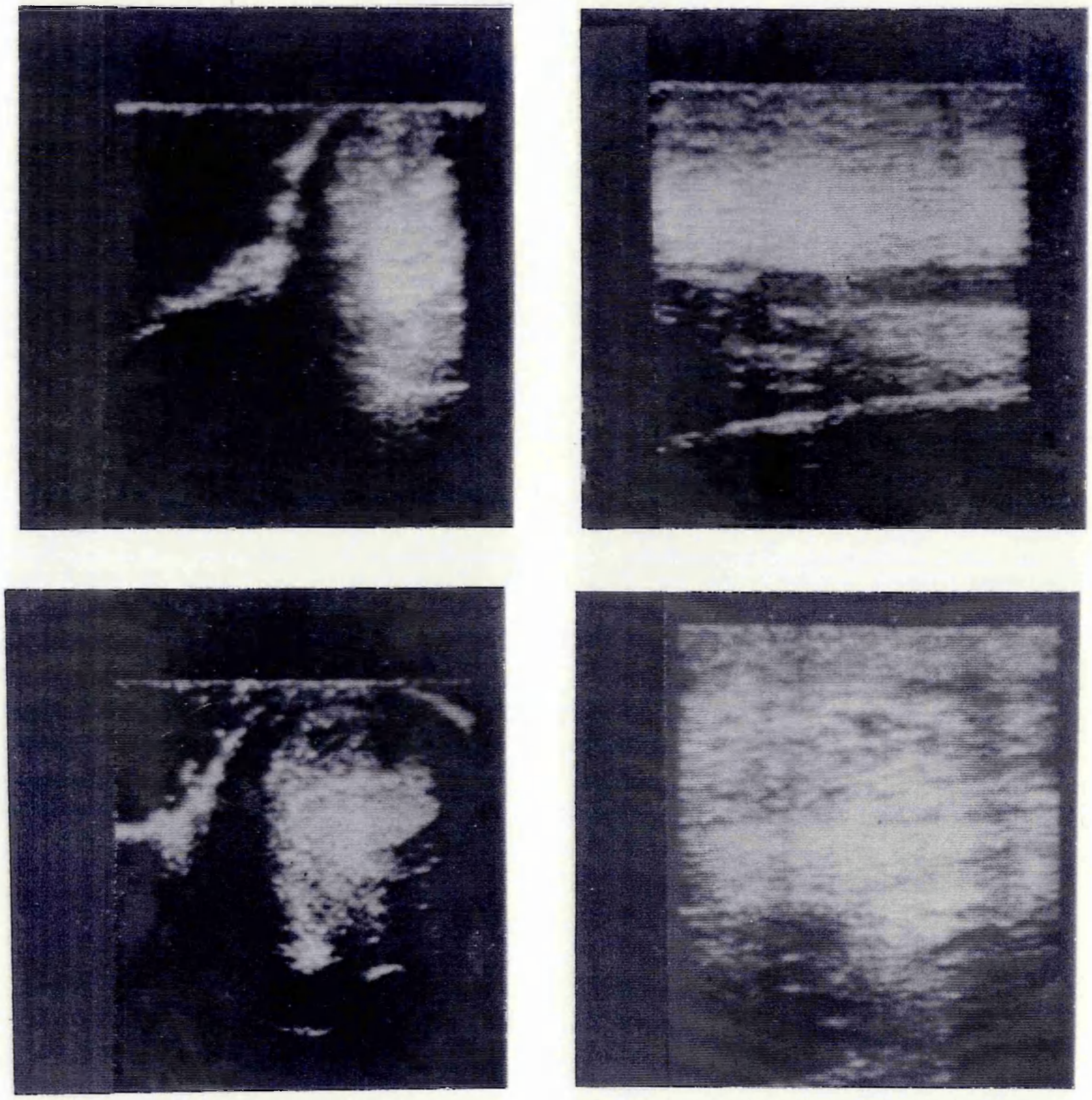
The severity of the lesion did not influence the recurrence rate in this group of animals (Table 5.6). However, the retiral rate was influenced by the severity of the lesion (Table 5.6). There was no difference in the ability to return to work between unilateral and bi-lateral injuries with the same severity in the most severely affected limb. All the horses with mild lesions returned to work and, when these horses were compared with the rest of the animals, a highly significant difference in the rate of return to work was detected ($p < 0.005$). The prognosis for return to work for severe lesions was poorer when compared to the mild and moderate groups ($p < 0.025$). The lay-off period for severe lesions was significantly longer ($p < 0.05$) than that for both moderate and mild lesions which was similar (no significant difference). Nevertheless, nine animals with extremely severe tendon lesions did race again and examples of the ultrasonographic findings in these horses are illustrated in Figure 5.16.

FIG. 5.16. EXAMPLES OF SEVERE SUPERFICIAL DIGITAL FLEXOR TENDON INJURY WHICH ULTIMATELY RACED AGAIN.

ULTRASONOGRAPHIC IMAGES OBTAINED AT SIX MONTHS' DURATION FROM CASE 5.39. THE MAJORITY OF THE CROSS-SECTIONAL AREA OF THE TENDON IS DISRUPTED WITH BOTH ANECHOIC AND HYPOECHOIC AREAS PRESENT (ECHOGENICITY GRADE 3, UPPER, LEFT). ON LONGITUDINAL IMAGES THE LINEAR ECHO FORMATION IS BEGINNING BUT IT IS EXTREMELY IRREGULAR (LINEAR ECHO GRADE 2, UPPER, RIGHT). THIS HORSE RACED THREE TIMES WITHOUT RECURRENCE FOLLOWING A LAY-OFF OF TWENTY-SIX MONTHS.

ULTRASONOGRAPHIC IMAGES OBTAINED AT SIX MONTHS DURATION FROM CASE 5.41. THE TRANSVERSE IMAGE (LOWER, LEFT) DEMONSTRATES THAT THERE ARE NUMEROUS HYPERECHOIC FOCI, THE ECHOGENICITY OF THE TENDON IS REDUCED AND HETEROGENEOUS THROUGHOUT THE ENTIRE CROSS-SECTIONAL AREA AND THE BORDER BETWEEN THE SUPERFICIAL AND DEEP DIGITAL FLEXOR TENDONS IS INDISTINCT. ON THE LONGITUDINAL IMAGE (LOWER, RIGHT), A LARGE ECHOGENIC STRUCTURE IS PRESENT BETWEEN THE SKIN AND THE FLEXOR TENDON WHICH IS COMPOSED OF UNIFORM HYPOECHOIC MATERIAL, THE ECHOGENICITY OF THE TENDON IS IRREGULAR AND LARGE ECHOGENIC FOCI AREA APPARENT BUT THE LINEAR ECHO FORMATION IS MINIMAL. THIS HORSE RACED THREE TIMES AS A POINT-TO-POINTER FOLLOWING EIGHTEEN MONTHS REST.

[NOTE THESE IMAGES ARE INVERTED AND THERE IS INSUFFICIENT CONTACT ON THE LATERAL ASPECTS OF BOTH TRANSVERSE IMAGES (LOWER AND UPPER, LEFT).



SECTION 5.4. DISCUSSION.

The ultrasonographic appearance of a flexor tendon injury was first reported by Spaulding, (1984), and subsequent reports have concluded that the most common type of acute injury is a central core lesion which generally appears as an anechoic or hypoechoic area within the tendon (Genovese and others, 1985; Rantanen and others, 1985; Genovese and others, 1986; Genovese and others, 1987; Reef and others, 1988). A study on iatrogenic tendon lesions has demonstrated that the echogenicity of the lesion increases progressively with age (Henry and others, 1986) and this finding has been supported by observations in clinical cases (Genovese and others, 1985; Rantanen and others, 1985; Genovese and others, 1986; Genovese and others, 1987; Reef and others, 1988).

The lesions in the majority of horses in this study were also anechoic or hypoechoic areas located within the tendon (Figs. 5.1, 5.4, 5.5 and 5.15; see also Figs. 3.1, 3.3, 3.5, 3.8, 3.13, 3.19, 3.20, 4.7 and 4.8). Hypoechoic lesions (Figs. 5.1 and 5.5) have been attributed to less extensive tendon lesions in which there is predominately infiltration with inflammatory fluid and minimal fibre disruption (Genovese and others, 1987; Reef and others, 1988). However, comparative histological and ultrasonographic studies in cases with similar lesions have demonstrated that haemorrhage and collagenolysis are present (Chapter 3). It has been suggested that the echogenicity of the lesion most closely represents the type of tissue present within the area of damage and the stage of healing rather than the severity of the lesion (Reef and others, 1988). Nevertheless, the majority of hypoechoic lesions were observed in the least severely affected animals in this study and, thus, it was concluded that this appearance was associated with less extensive tendon injury. However, there was no evidence to suggest that these injuries are any less significant than the anechoic areas of similar size.

Anechoic central lesions (Figs. 5.1, 5.4 and 5.15) were observed most frequently in the moderately severe subgroup, and these too are representative of haemorrhage, collagenolysis, fibrin deposition and, in their later stages, granulation tissue formation (Chapter 3).

The site and shape of these discrete lesions in transverse planes was variable and, although lesions located in the central area of the transverse images were most common, any area of the tendon could be affected (Reef and others, 1988). In terms of the longitudinal axis of the tendon, the mid and distal thirds of the metacarpal region were the most common sites for discrete lesions and this observation was consistent with the area which was reported to be the most common location for superficial digital flexor tendon injury in a post-mortem study (Webbon, 1977). It was not possible to reach any definite conclusions as to the site of injury in animals which had sustained a previous injury as the history in the majority of cases was felt to be insufficient. However, the general impression was that re-injuries tended to be longer and extend further into the distal portions of the tendon than the previous injury site. An exception was Case 5.9 in which a small asymmetrical lesion occurred in the distal third of a tendon which had previously sustained a severe injury affecting the majority of the length of the tendon (this case is also included in the study described in Chapter 4, see Fig. 4.7).

Complex lesions, occupying the majority of the tendon and composed of a heterogeneous mixture of anechoic and hypoechoic areas, have not been reported in the literature. They were observed in 30% of the flexor tendon injuries in this group with the majority of those being in severely affected animals. This study group had a high incidence of extremely severe lesions and this may explain the frequency of a lesion type which has not been reported previously. In part, this distribution of severity may be the result of the fact that prior to the onset of this study, horses were not routinely referred to Glasgow University Veterinary School for the investigation of tendon injury and the initial referrals for this study tended to be severely affected. This caseload was presumably the result of referring practitioners wishing to provide appropriate material. There was a general trend throughout the course of the study for the referred animals to be less severely affected and a greater number of negative examinations were performed latterly. However, it is probably also the case that the local equine referral population, being engaged in racing over fences, had a high incidence of severe tendon lesions which had ultrasonographic appearances which were not typical of, and were more extensive than, the lesions described previously (Genovese and others, 1985; Rantanen and others, 1985; Genovese and others, 1986; Genovese and others, 1987; Reef and others, 1988).

Only four of the 126 lesions departed markedly from the types described above: one horse (Case 5.58, Fig. 5.2) had a complete rupture of the superficial digital flexor tendon sustained during a gallop although the skin was bruised but remained intact. Another, (Case 5.72, Fig. 5.1) had two separate lesions within the superficial digital flexor tendon. This animal was examined within two days of sustaining this injury and, unfortunately, it was not possible to re-examine it until six months later at which time the most distal, smaller lesion was no longer apparent as a separate entity. It maybe that this area was only separate from the larger lesion in the earliest stages.

The diffuse, complete disruption in echogenicity which was observed in Cases 5.23 and 5.35 was also reported in association with widespread fibre disruption, fibrin deposition and haemorrhage in Chapter 3 (Case 3.2, Fig 3.7) but this ultrasonographic appearance has not been described in association with flexor tendon injury in the past. The coarse hypoechoic tissue which comprised the tendon was similar in appearance to the tissue which lay to the medial aspect of the deep digital flexor tendon at the site of complete rupture in Case 5.58 (Fig. 5.2) and may represent fragments of necrotic tendon fibres enmeshed with fibrin and haemorrhage.

Case 5.42 initially had a hypoechoic lesion which progressed within three weeks to an anechoic area. This could be explained by differences in the gain settings on the ultrasonographic unit on these two occasions. But, on review of the ultrasonograms in this case, it did appear that a true decrease in echogenicity had occurred during this time.

Ultrasonography has been advocated as a means of monitoring tendon healing and it has been possible to make recommendations for returning animals to training based on the ultrasonographic appearance (Genovese and others, 1985; Rantanen and others, 1985; Genovese and others, 1986; Genovese and others, 1987; Reef and others, 1988). However, a long-term study such as this has not been reported, and the identification of specific patterns of change in ultrasonographic appearance associated with healing of the lesion was considered to be desirable as it is only if the normal progression has been defined, that significant departures from this can be identified.

Examination of the data generated from the whole group allowed the identification of lesion echogenicity, the distinctness in lesion border and the linear echo formation as useful means of assessing healing. Both echogenicity and linear echo arrangement have been emphasised in this regard by other authors but the distinctness of the lesion border has received less attention (Genovese and others, 1987). The lesion border could only be assessed in the mild, moderate and those severe lesions which did not comprise the entire cross-sectional area of the tendon.

The echogenicity of the lesions gradually increased with time but in the majority (66%) of animals examined at greater than seventy-two weeks' duration in this study this parameter was not classified as normal (Table 5.1, Fig. 5.3). The frequency of observation of anechoic and anechoic and hypoechoic combination lesions decreased with the lesion duration and these appearances were features of lesions of less than or equal to sixteen weeks' duration. Other authors have reported that lesions are generally hypoechoic by four to eight weeks' duration and this difference may be the result of differences in the severity in this study population (Reef and others, 1988).

Lesions which were represented by well-defined hypoechoic areas in the acute stages and which remained hypoechoic throughout the course of healing appeared to heal most quickly. The overall echogenicity was normal with slight disruption of linear echo formation by sixteen weeks in two horses (Cases 5.12 and 5.38), and by twenty-six weeks in another horse (Case 5.22, right). However, in other animals with similar initial lesions, they were still present at twenty-six weeks' duration (5.52, 5.53, 5.90)

The earliest resolution of an anechoic lesion was in Case 5.13 in which the overall echogenicity was normal by thirty-six weeks after the initial insult. The appearance of those lesions which had been heterogeneous mixtures of anechoic and hypoechoic areas in their initial stages tended to remain heterogeneous as they healed with the anechoic regions gradually being replaced by hypoechoic areas (see Figs. 3.27, 3.32, 3.33, 3.34, 3.35). In addition, hyperechoic foci representative of scar formation (Chapter 3) were also commonly noted in these cases (Figs. 5.3 and 5.7; see also Figs. 3.24, 3.27, 3.32, 3.33, 3.34, 3.41, 3.41, 3.43 and 3.44).

At twenty-six weeks' duration, the majority of lesions were predominantly mixtures of hypoechoic areas, a finding which was consistent for the rest of the study period (Table 5.1, Fig. 5.4). Thus, identification of the echogenicity alone was not sufficient to distinguish the stage of healing. At this stage, the grading of the linear echo formation was extremely useful. The cumulative data for the group illustrated that progressive changes continued to occur from twenty-six to seventy-two and greater weeks' duration (Table 5.4, Fig.

5.11).

The general trend in the distinctness of the lesion border is less apparent when the cumulative data for the group are assessed. In a large number of cases, (20% of the ultrasonograms of lesions of less than four weeks' duration), a lesion border was not apparent due to the large size of the affected area. This continued to be the case throughout the study and, unfortunately, this method of analysis of the relative incidence of each grade of lesion border did not distinguish between lesion borders which were not apparent due to the lesion size and those that had previously been obvious which became less distinct as the lesion progressed. However, there was a gradual increase in the proportion of imperceptible lesion borders as the duration of injury increased, with grade 3 and 4 predominating in lesions of less than or equal to twenty-six weeks' duration and grades 1 and 2 becoming increasingly more frequent in the older lesions (Table 5.3, Fig. 5.10).

There was an increase in the proportion of grade 2 lesion borders in the ultrasonograms obtained from animals with lesions of greater than seventy-two weeks' duration. This can be accounted for by the fact that these data were obtained from a small number of individuals (six), all of which had relatively well-defined hypoechoic areas present in the distal third of the metacarpal region of the superficial digital flexor tendon which justified the allocation of grade 2. Such hypoechoic regions (Fig. 5.6; see also Fig. 3.32) were commonly observed in the chronic stages of healing and they were consistent with the appearance of areas of granulation tissue within a region of fibrotic tendon (Chapter 3) and, therefore, it is interesting to note that in some individuals they were found in extremely long-standing tendon injuries. Pathological studies have demonstrated that pockets of granulation tissue can be found within chronic lesions of up to fourteen months' duration and these ultrasonographic findings suggest that, in fact, they may persist for much longer periods (Silver and others, 1983). A similar area was present in one horse which was examined eighty weeks after the initial injury. It is also interesting to note that the majority of these well-defined hypoechoic areas were located in the distal third of the metacarpal region of the superficial digital flexor tendon which may indicate that there are regional differences in the rate of healing within the tendon or that the initial injury was most severe in this area.

In individual animals, the grade of linear echo formation increased (Fig. 5.13; see also Figs. 3.1, 3.3, 3.4, 3.5 [grade 0]; 3.31, 3.32 [grade 1] 3.32, 3.33, 3.35 [grade 2]; 3.40, 3.41 [grade 3] 3.34, 3.43, 3.45 [grade 4]) and the grade of the distinctness of the lesion border decreased gradually with time (Fig. 5.12; see also Figs. 3.1, 3.3, 3.4, 3.5, 3.8, 3.13 [grade 4], 3.20, 3.20, 3.31 [grade 3], 3.33, 3.34, 3.35 [grade 2]

3.41, 3.42 [grade 1]). But, a number of separate patterns of progression of echogenicity were identified which were dependent principally on the initial appearance of the lesion and, therefore, indirectly on the severity (Figs 5.4 and 5.5).

In Cases 5.23 and 5.35 both the initial ultrasonographic findings and those during healing were unusual. Large hyperechoic areas appeared approximately four weeks after the initial insult within the affected tendons which had previously been hypoechoic (Figs. 5.8 and 5.9). These areas were not like those associated with collagenous scar formation (Chapter 3) and have not been reported before. No histological correlation is available but these areas were presumably the result of the coagulation of large amounts of either fibrin or collagen. In both these cases, the lesions were extremely severe but, after twenty-six weeks, these areas were no longer present and the progression of healing resumed a more typical pattern of gradual resolution to a heterogeneously hypoechoic lesion with small hyperechoic foci representing scar formation (Chapter 3).

The effectiveness of ultrasonography in assessing peritendinous lesions was investigated and compared with that of negative contrast radiography in the study described in Chapter 4. In that study, and in the study comparing ultrasonographic and pathological findings described in Chapter 3, it was concluded that distinct echogenic structures between the skin and the superficial digital flexor tendon could be identified in some cases and that these were representative of proliferation of the paratenon and chronic subcutaneous inflammation while peritendinous haemorrhage and oedema produced an anechoic area around the superficial digital flexor tendon in the acute stages. Similar observations were made in the cases included in this study (Fig. 5.14, see also Figs. 3.24, 3.27, 3.24, 3.35, 3.40, 3.44 and 4.6). The excess peritendinous tissue was invariably located in the distal third of the metacarpal region in these horses and tendon injury in this site is known to lead to extensive subcutaneous fibrosis (Webbon, 1977). This region of the superficial digital flexor tendon was also the slowest to resolve in the majority of severe cases and the proliferation of the paratenon may be further evidence of regional differences in the mechanisms of tendon healing.

Adhesions between the deep and superficial digital flexor tendons have been associated with indistinctness of the boundary between these two structures (Genovese and others, 1985; Genovese and others, 1986; Genovese and others, 1987). However, as was noted in Chapter 4, frequently this ultrasonographic feature was difficult to assess and was felt to be subjective, particularly as in normal horses the clarity of this boundary may vary (Chapter 2). Adhesion formation has been considered as a cause of the high incidence of recurrence of tendon lesions and a number of therapeutic regimens are directed at the inhibition of this process (Selway, 1975; Whatmore and others, 1984). However, in a post-mortem study of 94 abnormal superficial digital flexor tendons, Webbon, (1977), reported that firm adhesions between the deep and superficial digital flexor tendon were present in only one horse. In the pathological examinations described in Chapter 3, adhesion formation was present to some extent in all chronic cases. Thus, the significance and true incidence of adhesion formation is controversial but it is unlikely that ultrasonographic studies will resolve this issue.

In this group of horses, previous injury was the only significant factor which was identified when the influences of age, sex and previous clinical history on severity were assessed. Increasing age might be expected to be associated with more severe lesions as the likelihood of previous injury increases, but in this group, age did not have a statistically significant effect on the severity of the lesions, although the proportion of severe lesions was higher in older animals (Webbon, 1979; Table 5.5).

Three factors, the work versus retiral rate, the recurrence rate and the duration of the lay-off period between the initial injury and the subsequent return to training, were chosen as end-points and used to investigate the eventual outcome in these cases. The reported rate of return to work has varied with the treatment regimen and the population studied: Bramlage (1986) describes the highest rate which was the completion of at least two races without recurrence of the injury in 79% of a mixed population of 35 horses treated with superior check ligament desmotomy. In Thoroughbreds racing on the flat, 64% successfully completed two races without recurrence if they were treated and rested whereas only 12% completed two races if rest was not instituted (Genovese and others, 1987). 36% of a group consisting mainly of Standardbreds, were able to race more than ten times and 29% were able to race at least once following a tendon splitting procedure (Nilsson and Bjorck, 1969; Nilsson, 1970). In this study, the rate of return to work within the whole group of animals in which the outcome was known (69 horses) was 42%.

There is a high incidence of recurrence associated with superficial digital flexor tendon injury in the horse and reports of the recurrence rate have varied from 18 to 50% depending on the breed and occupation of the horse and the treatment regimen (Nilsson and Bjorck, 1969; Goodship and others, 1980; Rooney and Genovese, 1981; Vaughan and others, 1985; Bramlage, 1986). The duration of the lay-off period has not been used as an end-point in the past, although some studies have utilised a defined time period at the end of which the outcome was assessed (Whatmore and others, 1984; McKibbin and Paraschak, 1983; Bramlage, 1986). Unfortunately, in those reports, the duration of the lesions at the onset of the evaluation period was not defined or standardised.

Mares had a significantly higher retiral rate than geldings and this can be explained by the fact that an alternative career, breeding, is available to these animals and this influence has been recognised in other studies (Nilsson and Bjorck, 1969). In those mares which did return to work, there was no significant difference in the recurrence rate or the duration of the lay-off period when compared to geldings. Older horses, over eight years' old, have raced less frequently following tendon splitting but in this study, age did not influence the retiral rate, the recurrence rate or the duration of the lay-off period (Webbon, 1979).

The severity of the initial injury as defined by ultrasonographic examination was the only factor which did significantly influence more than one of the parameters defining the outcome of the case. The retiral rate was significantly higher in the horses with at least one severe lesion although the prognosis was no worse if the injuries were bilateral. The retiral rate was lower in animals with mild unilateral and bilateral lesions. In addition, the lay-off period required for return to work was significantly longer in severe lesions but there was no differences in its duration between mild and moderate lesions. There was no difference in the recurrence rate associated with the severity and, in fact, the recurrence rate was higher in the moderately severe subgroup. However, this may refect differences in the duration of investigation of these animals.

The history of previous injury did not significantly alter the prognosis in these animals which is surprising because it was shown to influence the severity of the injury and only 50% of previously injured animals worked as opposed to 75% of previously normal animals. However, the history of these cases was known in only 31 animals with a known outcome and a larger study population may have demonstrated that this factor had a greater influence.

Polysulphated glycosaminoglycans are polymeric chains of repeating units of hexosamine and hexuronic acid. The efficacy of polysulphated glycosaminoglycans in treatment of degenerative joint disease has been reported and it is attributed to inhibition of protoeglycan-degrading lysosomal enzymes and neutral proteases thus inhibiting the destruction of proteoglycan and collagen in osteoarthritic cartilage (Yovich, Trotter, McIlwraith and others, 1987). It also results in synthesis of glycosaminoglycan by chondrocytes and increased hyaluronate synthesis by synovial cells (Yovich and others, 1987). The treatment of Achilles tendon sprain in laboratory animals with polysulphated glycosaminoglycans has produced encouraging results in an experimental situation (M.J. Clyne, personal communication). Nevertheless, the treatment of equine tendon injury with polysulphated glycosaminoglycans is based on empirical principles since its mode of action **in vivo** or **in vitro** has not yet been elucidated and the optimum dosage and route of administration have not been investigated.

Laser therapy has been advocated for the treatment of a variety of soft tissue injuries and in a study conducted in Standardbreds 66% returned to racing within 120 days (McKibbin and Paraschak, 1983). The biologic effects of laser irradiation include increased phagocytosis, promotion of angiogenesis and increased fibroblastic activity and rate of granulation tissue formation in wounds and **in vivo** studies in mice have demonstrated that the collagen content and tensile strength in skin wounds was enhanced by laser therapy (Mester, Spiry, Szende and others, 1971; Kami, Yoshimura, Nakajima and others, 1985; Lyons, Abergel, White and others, 1987). Conversely, irradiation of surgically-created skin and superficial digital flexor tendon injuries in horses produced no qualitative differences in histopathological response in a controlled study (Kaneps and others, 1984). There was no difference in eventual outcome irrespective of the treatment regimens employed in this study. A higher proportion of animals returning to work was expected in those horses in which active measures were employed to treat the animals and, although this was observed, the differences were not significant (Webbon, 1979).

A higher, but insignificant, difference in recurrence rate was observed in horses treated with polysulphated glycosaminoglycans which may be the result of the shorter mean lay-off period in these horses rather than a direct effect of the treatment regimen. In horses racing in Britain, recurrence rates of 33% and 50% have been associated with the treatment of tendon injuries with carbon fibre implants (Goodship and others, 1980; Vaughan and others, 1985). In this group of horses the overall recurrence rate was 35% with a mean lay-off period of 13.5 months with a range of six to twenty-six months. The recurrence rate in animals treated conservatively in this study was 19% and thus, this compares favourably with previous reports.

The main limitation of this investigation on the eventual outcome in superficial digital flexor tendon injury is that the total follow-up time each individual was studied varied with the minimum time being nine months. In many individuals, the eventual outcome remained unknown at the end of the study and the true rate of recurrence of injury was not established as some of these injuries can be expected to recurr in future. Equally, any study using retiral rate as an end-point is likely to be biased as, by participating in the study, the owners and trainers may be expressing the intention to work the animal again. However, the latter factor is likely to be more significant when using clinical material to assess treatment regimens where undoubtedly the aim is to return the animal to work (Webbon, 1979).

The duration of the lay-off period is ultimately determined by the trainer of the horse and, in some respects, this is likely to influence the eventual outcome rather than be a suitable end-point for analysis. Unfortunately, these limitations are unavoidable when investigations are based on clinical material, particularly in a disease with a protracted course such as superficial digital flexor tendon injury. All three factors were investigated as shortcomings were recognised in each one individually. The design of the study could have been improved by choosing a series of defined times at which the outcome was assessed. However, in view of the prolonged period required for such a study this was not possible although future analysis of the data generated in this study when the outcome after a number of years is known for all the animals will be useful.

A major difficulty encountered during this study was the limited access to the animals at the required times due mainly to the large number of individuals involved, the seasonal nature of the injury and the mobility of the study population. Horses were often unavailable at times when examinations were requested. However, to attempt to overcome this problem, the ultrasonographic changes both within the group as a whole and in individuals were considered and the details of the eventual outcome was obtained by telephone discussions with the trainers in cases in which the animal was no longer available for examination.

The conclusions of this study were that ultrasonography was a useful means of determining the severity of injury in the acute stages of superficial digital flexor tendon injury and that this influenced the outcome most whereas other factors such as the age, previous history and treatment regimen were not useful prognostic indicators. Small, hypoechoic lesions healed most rapidly with small anechoic lesions also carrying a more favourable prognosis. The echogenicity, the linear echo arrangement and the distinctness of the lesion borders changed as the lesion healed and several distinct patterns of progression of echogenicity were identified which could be related to the initial appearance and the severity of the lesion. Ultrasonography was effective in assessing subcutaneous haemorrhage and fibrosis but difficulty was experienced in the determination of the presence of adhesions between the superficial and deep digital flexor tendons.

CHAPTER 6.

STUDIES ON MICROWAVE THERMOGRAPHY OF THE PALMAR METACARPAL REGION - A NEW NON-INVASIVE DIAGNOSTIC TECHNIQUE FOR THE INVESTIGATION OF SUPERFICIAL DIGITAL FLEXOR TENDON INJURY IN THE HORSE.

SECTION 6.1. INTRODUCTION AND AIMS OF THE STUDY.

Infrared thermographic methods have been useful for the early diagnosis of tendon lesions in horses (Stromberg, 1971; Stromberg, 1973). Microwave thermography is a new non-invasive technique which has been advocated for diagnosis of a variety of soft tissue injuries in human medicine but its application in veterinary medicine is unreported (Barrett et al, 1980; Myers et al, 1980; Fraser et al, 1987; Stallard et al, 1987).

The first aim of this study was to document the microwave thermographic findings in normal horses and to establish if clipping of the hair influenced the results. Secondly, the microwave thermographic abnormalities associated with acute superficial digital flexor tendon injury were recorded and used to design objective criteria to evaluate the thermographs by comparison of these results with those from normal horse and horses with soft tissue injuries in the metacarpal region. The thermographic features of chronic flexor tendon injury were defined and the diagnostic potential of the technique in these injuries determined by comparison of the findings with normal horses and horses with soft tissue injuries in the metacarpal region.

A separate study was designed to investigate the potential of the technique as a screening tool to detect early or subclinical tendon injury by monitoring horses in training on a regular basis.

PART 6.1. STUDIES ON THE MICROWAVE THERMOGRAPHIC FINDINGS IN NORMAL HORSES.

STUDY 6.1.1. THE DEVELOPMENT OF THE EXAMINATION TECHNIQUE AND CRITERIA FOR EVALUATION OF MICROWAVE THERMOGRAPHIC DATA IN NORMAL HORSES.

SECTION 6.1.1.1. MATERIALS AND METHODS.

Animals.

A total of seventy seven horses was included in the study. Group 6.1 comprised sixteen Thoroughbred or Thoroughbred cross horses with clinically normal superficial digital flexor tendons. Their ages ranged from five to twenty five years with a mean of thirteen years. The horses were all permanently retired from physical work and were housed in a loose yard system.

Group 6.2 was formed by sixty six Thoroughbred horses in which their work varied from none to full training for National Hunt racing. Their ages ranged from three to twenty plus years with a mean of eight years.

The criteria for inclusion were no known history of tendon injury and no clinical signs indicative of current or previous tendon injury. Ultrasonographic examination was performed following the thermographic studies in group 6.1 to confirm the normality of the superficial and deep digital flexor tendons, the inferior check ligament and the suspensory ligament but such an examination was not performed in group 6.2.

Thermographic examination.

The hair was removed prior to the evaluation process in group 6.1 but not in group 6.2. The thermographic examination was performed using a microwave thermographic unit. The temperature was recorded from thirteen locations at approximately 3 cm intervals: three proximal to the accessory carpal bone; seven at sites situated from proximal to distal in the metacarpal region and three distal to the metacarpophalangeal joint (Fig. 6.1). The aerial was held in place for approximately two seconds and the temperature was recorded in degrees Celsius.

Evaluation of thermographs.

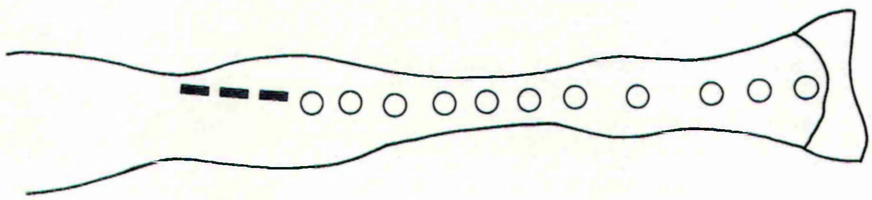
The mean temperature for each thermograph was calculated, and the maximum temperature difference between similar locations in the contralateral limbs was determined.

The temperature at each location was plotted and the temperature profile was evaluated. A classification system was designed which described the warmest and coldest parts of the limb.

Mathematical and Statistical Analysis.

The frequency of observation of each temperature profile was recorded and the mean temperatures of each limb was determined. The incidence of each recorded value for the mean temperature of the left limbs, the mean temperature of the right limbs, the difference in the means of each pair of limbs and the maximum temperature difference between symmetrical points in

FIG. 6.1. THE MICROWAVE THERMOGRAPHIC UNIT IN USE WITH A LINE DIAGRAM TO ILLUSTRATE THE LOCATIONS OF EACH RECORDING SITE IN THE PALMAR METACARPAL REGION.



contralateral limbs was determined. The mean and standard deviations of the mean temperatures of each limb, the mean difference between the limbs and the maximum temperature between the limbs were calculated and normal ranges were developed by calculating the mean plus or minus two standard deviations as the normal. The mean temperatures of the left and right fore limbs were compared using a paired Student's T test.

SECTION 6.1.1.2. RESULTS.

The thermographic data which were recorded in the normal horses is recorded in Appendices 6.1 and 6.2.

The Mean Temperature Of The Carpal, Metacarpal And Phalangeal Regions.

The means and standard deviations of the mean temperatures are listed in Table 6.1. There was a wide range observed in both right and left limbs and, as is illustrated in Fig. 6.2., the distribution of the individuals was not even around the mean. There was no significant difference between the mean temperatures of the left and right limbs.

The Differences Between The Mean Temperatures And Maximum Temperature Difference Between Symmetrical Points.

The mean, standard deviation and range of the difference between the mean temperature and the maximum temperature difference between symmetrical points are listed in Table 6.1. The differences in mean temperature between contralateral limbs were low in the majority of cases.

The range determined from the mean plus or minus two standard deviations was 0 - 2.89°C but the majority of normal horses fell well below this level (Fig 6.3). Similarly, the majority of normal horses did not approach the upper range for maximum temperature difference of 5.33°C determined by the same method. However, this is to be expected as neither parameter displayed a normal distribution around the mean (Figs. 6.3 and 6.4).

Temperature Profiles.

The temperature profile in each thermograph could be classified into one of the following groups:

A: The mid part of the graph demonstrated a decrease in temperature of greater than 1°C (Fig. 6.5).

B: The temperature profile decreased progressively in the distal locations by greater than 1°C (Fig 6.6).

C: The mid part of the graph demonstrated an increase in temperature of more than 1°C (Fig 6.7).

E: The temperature profile did not fluctuate by more than 1°C either upwards or downwards (Fig 6.8).

The frequency of observation of each profile is listed in Table 6.2. 59.7% displayed symmetrical profiles while in the remainder the profile was different in each limb. Profile A was observed slightly more frequently than Profile B. Profile E was observed in 6 limbs while Profile C was the least common and was observed in 4 limbs.

	GROUP 6.1	GROUP 6.2	TOTAL
SAMPLE SIZE	16	61	77
LEFT MEAN (°C)	27.45	32.21	31.22
S.D.	3.18	2.18	3.09
LEFT MIN (°C)	21.36	22.83	21.36
LEFT MAX (°C)	32.1	35.06	35.06
LEFT MEAN +/- 2 S.D. = 25.04 - 37.40oC			
RIGHT MEAN (°C)	28.41	32.06	31.30
S.D.	2.87	2.04	2.68
RIGHT MIN (°C)	22.44	27.19	22.44
RIGHT MAX (°C)	32.38	35.56	35.56
RIGHT MEAN +/- 2 S.D. = 25.94 - 36.66°C			
MEAN DIFF (°C)	1.52	0.67	0.85
S.D.	1.38	0.82	1.02
MEAN DIFF +/- 2 S.D. = 0 - 2.89°C			
MAX DIFF (°C)	3.21	2.10	2.33
S.D.	1.43	1.41	1.5
MAX DIFF +/- 2 S.D. = 0 - 5.33°C			

left mean = mean temperature of the left fore limb
right mean = mean temperature of the right fore limb
mean diff = the difference in the mean temperature of the fore limbs
max diff = the maximum difference in temperature of the fore limbs between fore limbs

TABLE 6.1. MEANS, STANDARD DEVIATIONS AND RANGES OF THE MEAN LIMB TEMPERATURE, THE DIFFERENCE IN MEANS BETWEEN CONTRALATERAL LIMBS AND THE MAXIMUM DIFFERENCES OBSERVED BETWEEN CONTRALATERAL LIMBS IN MICROWAVE THERMOGRAPHS OBTAINED FROM A GROUP OF SEVENTY-SEVEN NORMAL HORSES.

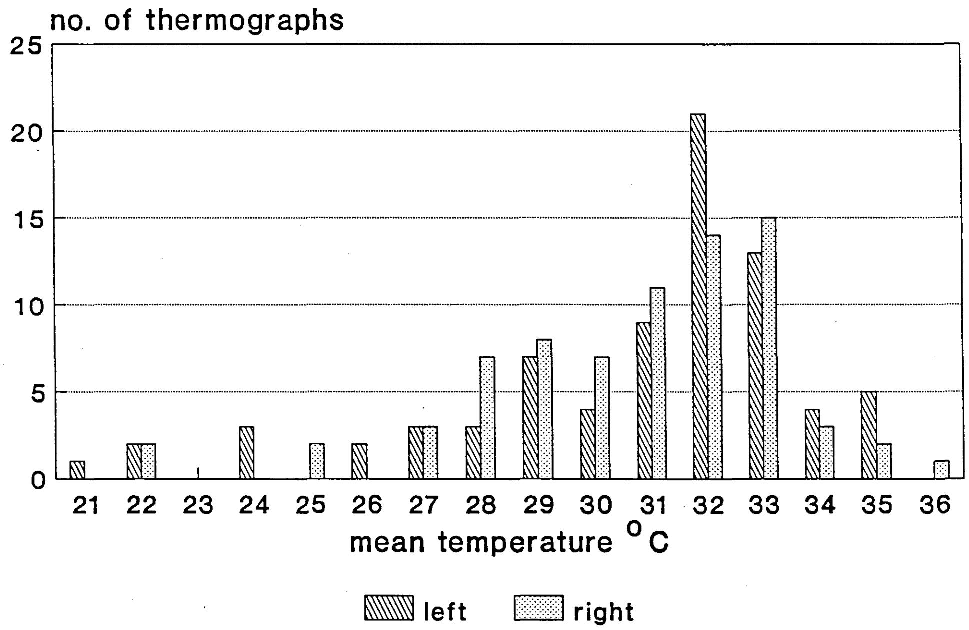


FIG. 6.2. THE FREQUENCY OF OBSERVATION OF EACH MEAN TEMPERATURE IN MICROWAVE THERMOGRAPHS RECORDED FROM THE LIMBS OF SEVENTY-SEVEN NORMAL HORSES.

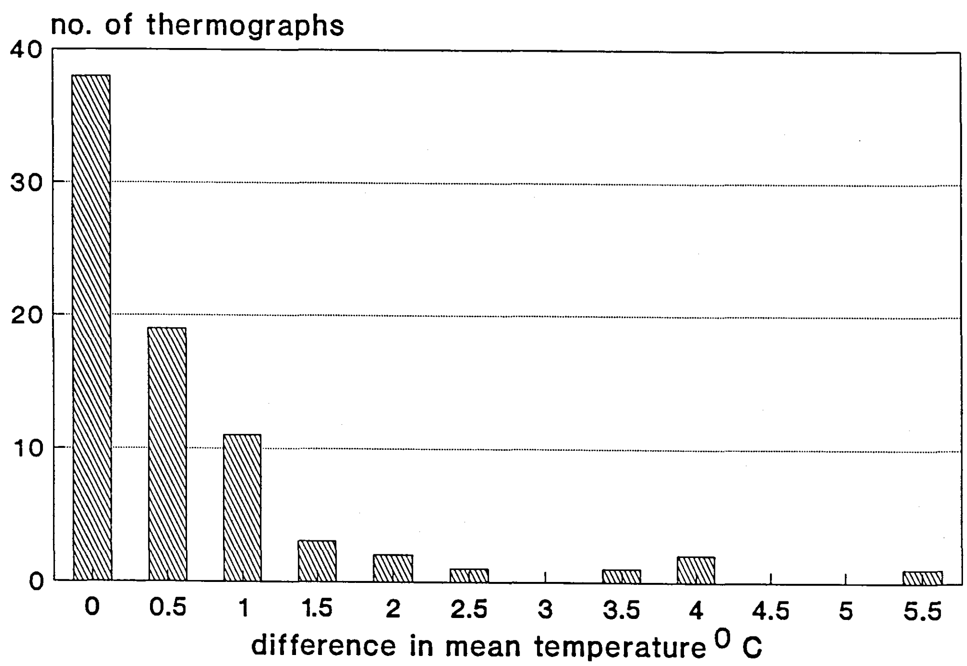


FIG. 6.3. THE FREQUENCY OF OBSERVATION OF EACH DIFFERENCE IN MEAN TEMPERATURE IN MICROWAVE THERMOGRAPHS RECORDED FROM THE SEVENTY-SEVEN NORMAL HORSES.

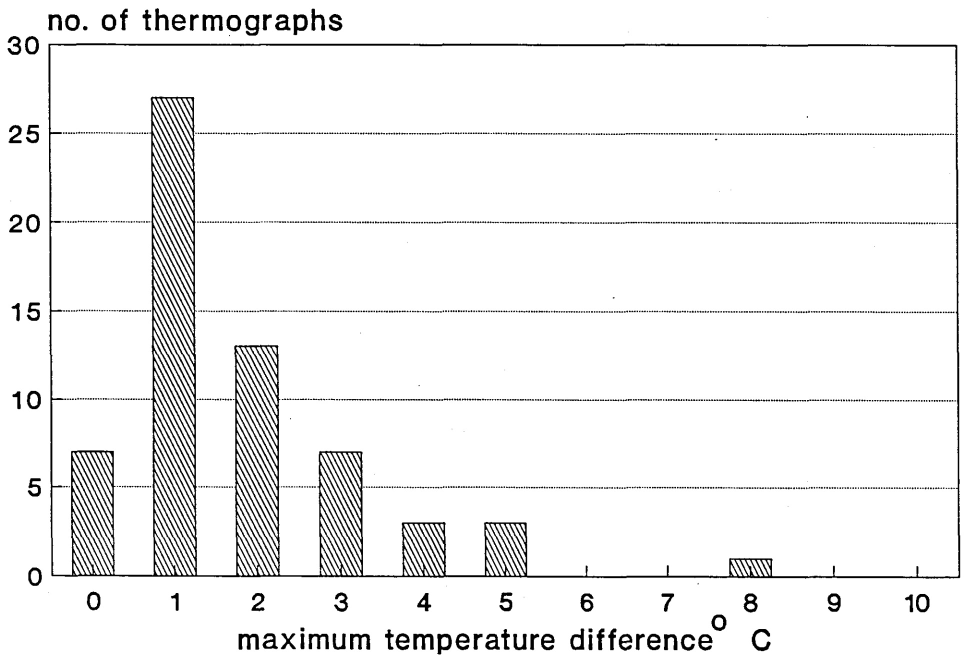


FIG. 6.4. THE FREQUENCY OF OBSERVATION OF EACH MAXIMUM TEMPERATURE DIFFERENCE BETWEEN BILATERALLY SYMMETRICAL POINTS IN MICROWAVE THERMOGRAPHS RECORDED FROM SEVENTY-SEVEN NORMAL HORSES

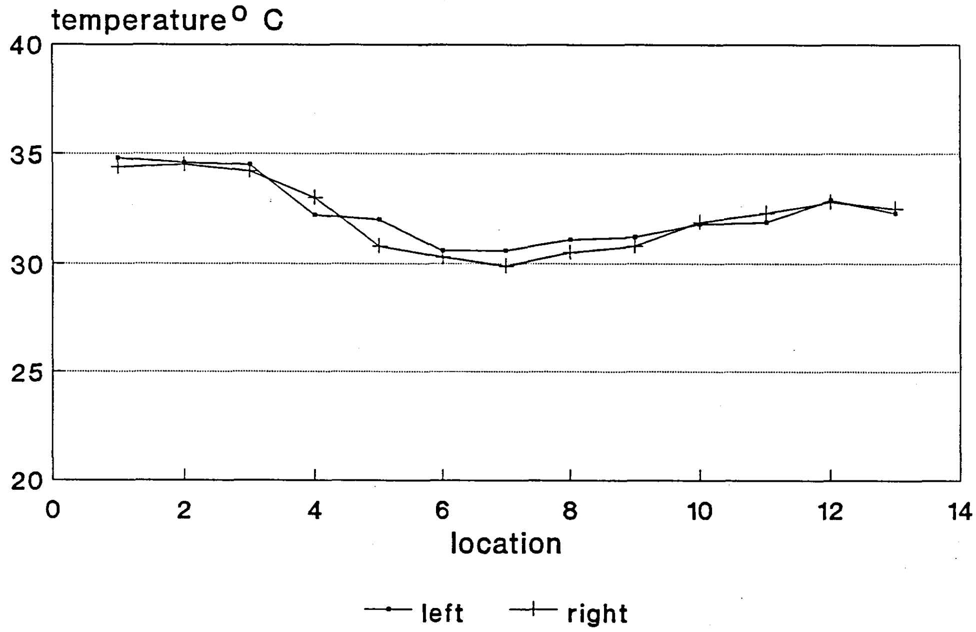


FIG. 6.5. A MICROWAVE THERMOGRAPH RECORDED FROM A NORMAL HORSE DEMONSTRATING TEMPERATURE PROFILE A: THE MID PART OF THE THERMOGRAPH DEMONSTRATE A DECREASE IN TEMPERATURE OF GREATER THAN 1°C.

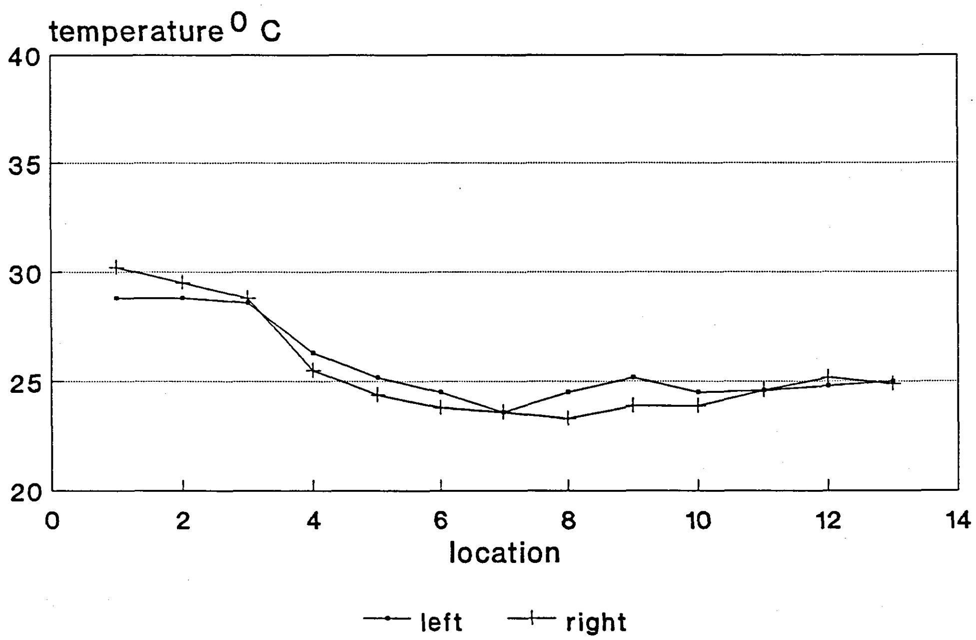


FIG. 6.6. A MICROWAVE THERMOGRAPH RECORDED FROM A NORMAL HORSE DEMONSTRATING TEMPERATURE PROFILE B: THE TEMPERATURE DECREASES PROGRESSIVELY IN THE DISTAL LOCATIONS BY GREATER THAN 1°C.

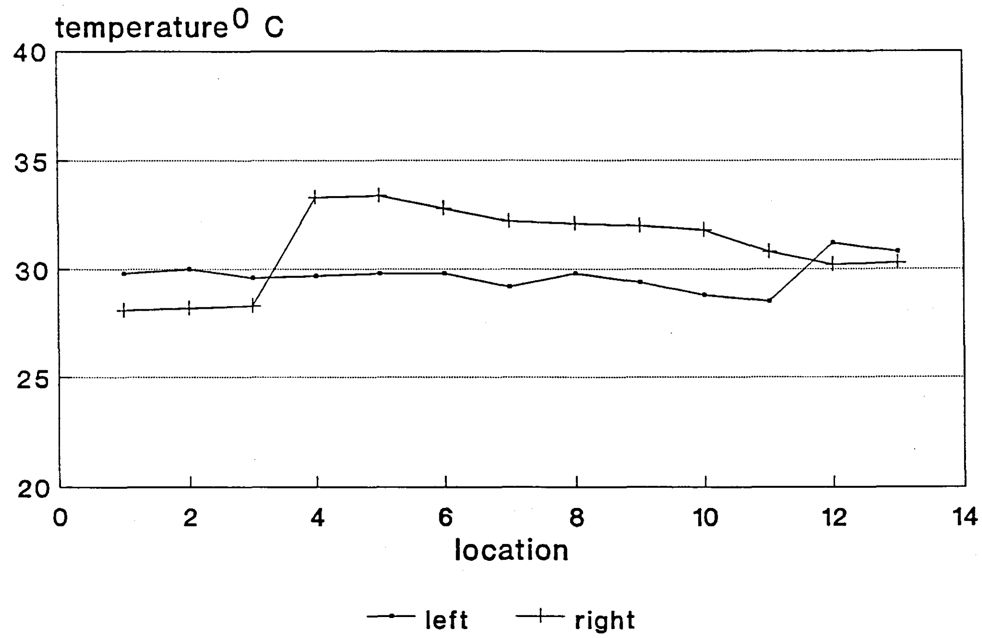


FIG. 6.7. A MICROWAVE THERMOGRAPH RECORDED FROM A NORMAL HORSE DEMONSTRATING TEMPERATURE PROFILE C: THE MID PART OF THE THERMOGRAPH DEMONSTRATES AN INCREASE IN TEMPERATURE OF MORE THAN 1°C.

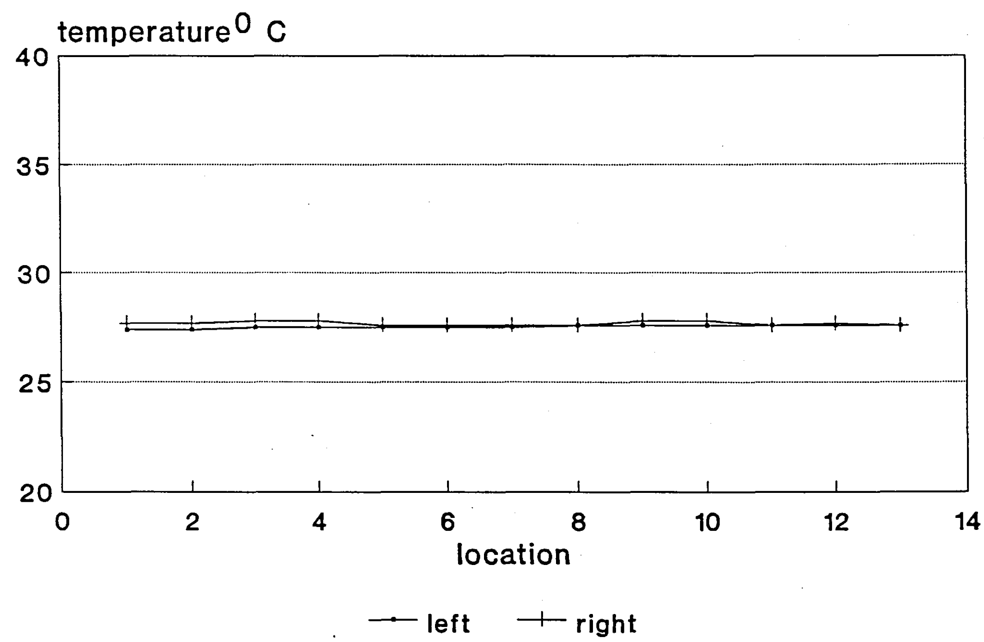


FIG. 6.8. A MICROWAVE THERMOGRAPH RECORDED FROM A NORMAL HORSE DEMONSTRATING TEMPERATURE PROFILE E: THE TEMPERATURE DOES NOT FLUCTUATE MORE THAN 1°C.

	GROUP 6.1	GROUP 6.2	TOTAL
NUMBER	16	61	77
LEFT A(%)	8(50)	31(50.8)	39(50.6)
LEFT B(%)	8(50)	25(40.9)	33(42.8)
LEFT C(%)	0	1(1.6)	1(1.2)
LEFT E(%)	0	4(6.5)	4(5.1)
RIGHT A(%)	10(62.5)	31(50.8)	41(53.2)
RIGHT B(%)	4(25)	27(44.2)	31(50.8)
RIGHT C(%)	2(12.5)	1(1.6)	3(3.8)
RIGHT E(%)	0	2(1.6)	2(2.6)
BOTH A(%)	18(56.2)	62(50.8)	80(51.9)
BOTH B(%)	12(37.5)	52(42.6)	64(41.5)
BOTH C(%)	2(6.3)	2(1.6)	4(2.5)
BOTH E(%)	0	6(4.9)	6(3.8)
SYMMETRICAL	10(62.5)	36(59.0)	46(59.7)
SYMMETRICAL A	7(43.7)	22(36.1)	29(37.6)
SYMMETRICAL B	3(18.7)	14(22.9)	17(22.1)

TABLE 6.2. THE FREQUENCY OF OBSERVATION OF EACH TEMPERATURE PROFILE AND BILATERAL SYMMETRY OF TEMPERATURE PROFILES IN MICROWAVE THERMOGRAPHS OBTAINED FROM SEVENTY-SEVEN NORMAL HORSES.

PART 6.1, STUDY 6.1.2. THE EFFECTS OF REMOVAL OF THE HAIR ON THERMOGRAPHIC FEATURES OF THE PALMAR METACARPAL REGION IN HORSES WITH ULTRASONOGRAPHICALLY NORMAL SUPERFICIAL DIGITAL FLEXOR TENDONS.

SECTION 6.1.2.1. MATERIALS AND METHODS.

Animals.

Sixteen Thoroughbred or Thoroughbred cross horses with clinically normal superficial digital flexor tendons were examined (group 6.1). The horses were all permanently retired from physical work and were housed in a loose yard system. Prior to, and following, the thermographic examination the hair was removed from the palmar aspect of the metacarpal region with surgical clippers. Following the thermographic examination the remainder of the hair was removed by shaving and ultrasonographic examination was performed to confirm the normality of the superficial and deep digital flexor tendons, the inferior check ligament and the suspensory ligament.

Thermographic Examination.

Thermographic examination was performed as described in Section 6.1.1. but was performed both prior to and following removal of the hair.

Evaluation of thermographs.

The mean temperature for each thermograph was calculated, and the maximum temperature difference between similar locations in the contralateral limbs was determined.

The temperature at each location was plotted and the temperature profile was evaluated and classified as described in Section 6.1.1.

Statistical analysis.

A paired Student's T test was performed to compare the mean temperatures of contralateral limbs and to compare the temperatures recorded prior to and following removal of the hair.

SECTION 6.1.2.2. RESULTS.

The data which were recorded are listed in Appendix 6.1. There was no significant difference between the mean temperature of the left and right limbs. Although the data recorded following removal of the hair tended to produce a lower mean temperature, there was no significant difference between the results obtained prior to and after clipping.

The removal of the hair did not affect the overall shape of the temperature profiles in any case but the precise location of the maximum difference between limbs was not consistent.

PART 6.2. STUDIES ON THE MICROWAVE THERMOGRAPHIC FINDINGS OF THE PALMAR METACARPAL REGION IN HORSES WITH SUPERFICIAL DIGITAL FLEXOR TENDON INJURY.

SECTION 6.2.1. MATERIALS AND METHODS.

Animals.

Horses presented for the investigation and evaluation of superficial digital flexor tendon were examined. These individuals had injuries of varying durations when they were first introduced into the study group and the majority were examined on several occasions ranging from three days to several weeks apart. The thermographs were grouped according to the duration of the injuries and these groups were: 6.3. four weeks duration or less; 6.4. five to eight weeks duration; 6.5. nine to twelve weeks duration; 6.6. thirteen to sixteen weeks duration; 6.7. seventeen to twenty-eight weeks duration; 6.8. twenty-nine to fifty-two weeks duration; 6.9. greater than fifty-two weeks duration. A further group, group 6.10, of animals which were presented for investigation of injury of the other soft tissue structures in the metacarpal region, was also examined.

Thermographic Examination.

The hair was removed prior to the evaluation and thermographic examination was performed as is described in Section 6.1.1.

Evaluation Of Thermographs.

The mean temperature for each thermograph, the difference in the mean temperature of each thermograph and the maximum temperature difference between similar locations in the contralateral limbs were determined.

The temperature at each location of the thermograph was plotted and the temperature profile was evaluated and classified according to the location of the warmest and coldest regions of the thermograph.

Mathematical And Statistical Analysis.

The mean temperatures of unaffected legs were compared with those of acutely and chronically affected legs by a paired Student's T test using data collected from those individuals which had sustained unilateral injuries.

A graph was constructed using the data collected from groups 6.1, 6.3 and 6.10. to define the overlap between the mean and maximum temperature difference between limbs in normal and diseased limbs

Various values, or cut-off points, of the diagnostic criteria were tested for their ability to distinguish the diseased from the normal state and the following parameters were tested to determine their effectiveness as selector variables or diagnostic criteria:

1. Temperature profiles which varied from those identified in normal horses.

2. The mean difference between the thermographs from the right and left limbs at various cut-off points.

3. The maximum difference between the contralateral locations at various cut-off points.

4. The mean temperature of the limb.

The sensitivity and specificity of these parameters alone, and in various combinations, were determined using the following formulae:

$$\text{Sensitivity} = \frac{\text{true positives}}{\text{true positives plus false negatives}}$$

$$\text{Specificity} = \frac{\text{true negatives}}{\text{true negatives plus false positives}}$$

Receiver operator curves were constructed to compare the effectiveness of some of the selector variables and the most effective parameters for separating the affected and unaffected animals were evaluated in group 6.3. Subsequently, the effectiveness of these parameters was tested in the animals with injuries of longer duration. The purpose of this was twofold: firstly, to ascertain if these were indeed effective parameters; secondly, to investigate the influence that the duration of the lesion had on the usefulness of the test.

SECTION 6.2.2. RESULTS.

A total of 402 individual thermographs were recorded in 68 horses, 56 of these horses had superficial digital flexor tendon injury while the remaining 12, (group 6.10), had various other injuries which included suspensory ligament injury (one), inferior check ligament injury (five), subcutaneous swelling associated with trauma (four) and skin wounds (two) and details of the thermographs obtained from these animals are listed in Appendix 6.3.

The superficial digital flexor tendon injuries were bilateral in eighteen cases and, therefore, a total of 74 injured limbs were investigated and there was equal proportions of left and right lesions. The number of examinations was distributed as follows: Group 6.3, less than four weeks' duration, 48 examinations of 60 affected and 36 normal limbs; group 6.4, five to eight weeks' duration, 41 examinations of 63 affected and 19 normal limbs; group 6.5, nine to 12 weeks' duration, 18 examinations of 25 affected and 11 normal limbs, group 6.6, 13 to 16 weeks' duration thirteen examinations of 20 affected and six normal limbs; group 6.7, 17 to 28 weeks' duration, 17 examinations of 24 affected and ten normal limbs; group 6.8, 29 to 52 weeks' duration, 23 examinations of 29 affected and 17 normal limbs and group 6.9, greater than 52 weeks' duration, 29 examinations of 39 affected and 19 normal limbs. Details of the thermographic data are listed in Appendices 6.4 to 6.10.

Comparison of the mean temperature of affected legs with that of the unaffected leg demonstrated that in the groups of horses with injuries of less than eight weeks duration the affected limbs had higher mean temperatures and there was a highly significant difference between the mean temperatures of the affected and unaffected limbs ($P < 0.0001$). In contrast, the data collected from horses with unilateral injuries of greater than eight weeks' duration tended to have higher mean temperatures in the affected limb when these data were taken as one group. The difference in mean temperature between affected and unaffected limbs was not statistically significant.

In addition to the temperature profiles described in Section 6.1.1, two further patterns were observed and these were:

D: The thermographic temperature profile increased progressively in the distal locations by greater than $1^{o}C$ (Fig. 6.9).

F: There was a localised increase in temperature in the metacarpal region which did not exceed the temperatures recorded in the remainder of the limb by more than $1^{o}C$ (Fig. 6.10).

The frequencies of observation of each temperature profile in the abnormal and normal limbs in each group are listed in Table 6.3. Profile B was the most commonly observed in the normal limbs but there was a relatively high incidence of Profiles C, D, E, and F in these limbs. Profile C was the most common pattern in the diseased limbs as a whole but Profiles A and B were observed with increasing frequency in the more chronic injuries.

The mean temperature of each limb is listed in Appendices 6.3 to 6.10. None of the limbs demonstrated a mean temperature above the normal range defined in

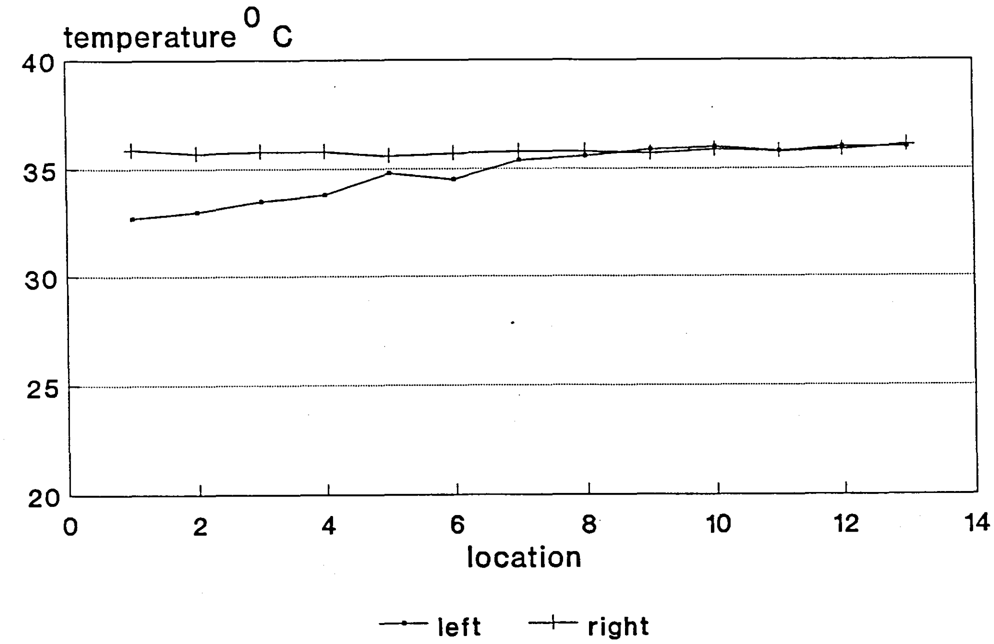


FIG. 6.9. A MICROWAVE THERMOGRAPH RECORDED FROM A HORSE WITH A LEFT SUPERFICIAL DIGITAL FLEXOR TENDON INJURY WHICH DEMONSTRATES TEMPERATURE PROFILE D: THE TEMPERATURE INCREASES PROGRESSIVELY IN THE DISTAL LOCATIONS BY GREATER THAN 1°C.

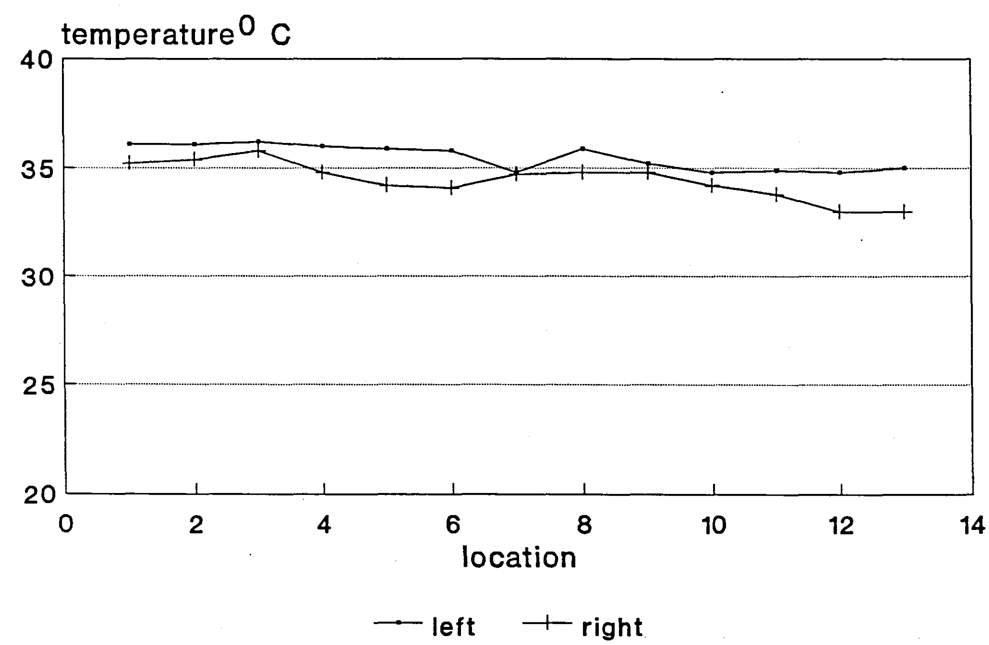


FIG. 6.10. A MICROWAVE THERMOGRAPH RECORDED FROM A HORSE WITH A LEFT SUPERFICIAL DIGITAL FLEXOR TENDON INJURY WHICH DEMONSTRATES TEMPERATURE PROFILE F: THERE IS A LOCALISED INCREASE IN TEMPERATURE IN THE METACARPAL REGION WHICH DOES NOT EXCEED THE TEMPERATURES RECORDED IN THE CARPAL REGION BY MORE THAN 1°C.

GROUP	NORMAL LIMBS (%)					
	A	B	C	D	E	F
6.1	18(56)	12(37)	2(6)	0	0	0
6.2	62(50)	52(43)	2(1)	0	6(4)	0
6.3	10(27)	18(50)	2(5)	4(11)	1(2)	1(2)
6.4	5(26)	12(63)	1(5)	1(5)	0	0
6.5	2(18)	3(27)	2(18)	3(27)	0	1(9)
6.6	2(33)	0	1(16)	2(33)	0	1(16)
6.7	2(20)	2(20)	1(10)	2(20)	3(30)	0
6.8	8(47)	4(23)	1(5)	0	3(17)	1(5)
6.9	4(21)	9(47)	2(10)	1(5)	2(10)	1(5)
6.10	3(25)	5(41)	0	1(4)	0	3(12)
	ABNORMAL LIMBS (%)					
6.3	4(7)	8(15)	29(48)	11(18)	1(2)	7(11)
6.4	8(13)	17(26)	25(39)	7(11)	3(4)	3(4)
6.5	6(24)	4(16)	8(32)	5(20)	0	2(8)
6.6	6(30)	5(25)	4(20)	2(10)	1(5)	2(10)
6.7	5(20)	8(33)	3(13)	3(13)	2(9)	3(13)
6.8	12(42)	2(7)	5(17)	4(14)	0	6(21)
6.9	13(33)	9(23)	1(2)	4(10)	9(23)	3(8)
6.10	2(16)	3(18)	6(50)	0	0	1(8)

TABLE 6.3. THE FREQUENCY OF OBSERVATION OF EACH TEMPERATURE PROFILE IN THE ABNORMAL AND NORMAL LIMBS RECORDED IN 154 THERMOGRAPHS FROM NORMAL HORSES (GROUPS 6.1 AND 6.2) AND 402 THERMOGRAPHS FROM 56 HORSES WITH SUPERFICIAL DIGITAL FLEXOR TENDON INJURY (GROUPS 6.3 TO 6.9) AND 12 HORSES WITH VARIOUS SOFT TISSUE INJURIES IN THE METACARPAL REGION (GROUP 6.10).

GROUP	NUMBER OF THERMOGRAPHS			
	ALL THERMOGRAPHS		NORMAL THERMOGRAPHS	
	TOTAL	<25.04°C	TOTAL	<25.04°C
6.3	96	20	36	12
6.4	82	19	19	10
6.5	36	2	11	0
6.6	26	7	6	1
6.7	34	3	10	0
6.8	46	8	17	4
6.9	58	5	19	2
6.10	24	0	12	0

TABLE 6.4. THE NUMBER OF THERMOGRAPHS WITH A MEAN CONTRALATERAL LIMB TEMPERATURE BELOW THE NORMAL RANGE (<25.04°C) IN 402 MICROWAVE THERMOGRAPHS FROM 56 HORSES WITH SUPERFICIAL DIGITAL FLEXOR TENDON INJURIES (GROUPS 6.3 - 6.9) AND 12 HORSES WITH VARIOUS SOFT TISSUE INJURIES OF THE METACARPAL REGION (GROUP 6.10).

Section 6.1.1. However, several individuals displayed mean temperature profiles below the normal range of 25.04^{o}C which was defined with data from groups 6.1 and 6.2 (Table 6.4). In several individuals, particularly in Groups 6.4 and 6.5, the limbs which had decreased mean temperature were contralateral to an injured limb.

The ability of microwave thermography to differentiate the normal from the diseased situation, by definition of various levels of difference in the means as abnormal, was investigated: as the value described as positive was decreased to increase the sensitivity, conversely, the specificity decreased (Table 6.5, Fig. 6.11). A similar effect was apparent when the sensitivity and specificity of the various values of maximum difference between limbs were examined, and the sensitivity decreased, and the false positive rate increased, as the specificity increased (Table 6.5, Fig. 6.11). Combinations of mean and maximum differences were tested, but the sensitivity and specificity of these parameters were poor. Again, as the criteria were made harder to improve the specificity, the sensitivity was reduced (Tables 6.6 and 6.7, Figs. 6.12 and 6.13).

The mean differences in temperature were plotted against maximum temperature differences between limbs using data recorded from groups 6.1, 6.3 and 6.10 (Fig. 6.14). This graph (Fig. 6.14) demonstrated that there was considerable overlap between the groups but that

DIFFERENCE IN MEAN TEMPERATURE	TRUE POSITIVE RATE (%)	TRUE NEGATIVE RATE (%)	FALSE POSITIVE RATE (%)
> 0.06 ^{o}C	100	0	100
> 1 ^{o}C	81	50	50
> 2 ^{o}C	64	68	32
> 3 ^{o}C	58	81	19
> 4 ^{o}C	43	87	13
> 5 ^{o}C	35	100	0
MAXIMUM DIFFERENCE IN TEMPERATURE			
> 0.4 ^{o}C	100	0	100
> 1 ^{o}C	97	0	100
> 2 ^{o}C	87	18	82
> 3 ^{o}C	72	62	38
> 4 ^{o}C	66	75	25
> 5 ^{o}C	60	81	19
> 6 ^{o}C	50	93	7
> 7 ^{o}C	39	100	0

TABLE 6.5. THE SENSITIVITY, SPECIFICITY AND FALSE POSITIVE RATE OF MICROWAVE THERMOGRAPHIC EXAMINATION USING THE DIFFERENCE IN MEAN TEMPERATURE AND MAXIMUM TEMPERATURE DIFFERENCE AS THE SEPARATOR VARIABLES WITH VARIOUS POSITIVITY CRITERIA IN 48 THERMOGRAPHIC EXAMINATIONS OF 28 HORSES WITH ACUTE SUPERFICIAL DIGITAL FLEXOR TENDON INJURY (GROUP 6.3) AND 16 THERMOGRAPHIC EXAMINATIONS RECORDED FROM NORMAL HORSES (GROUP 6.1).

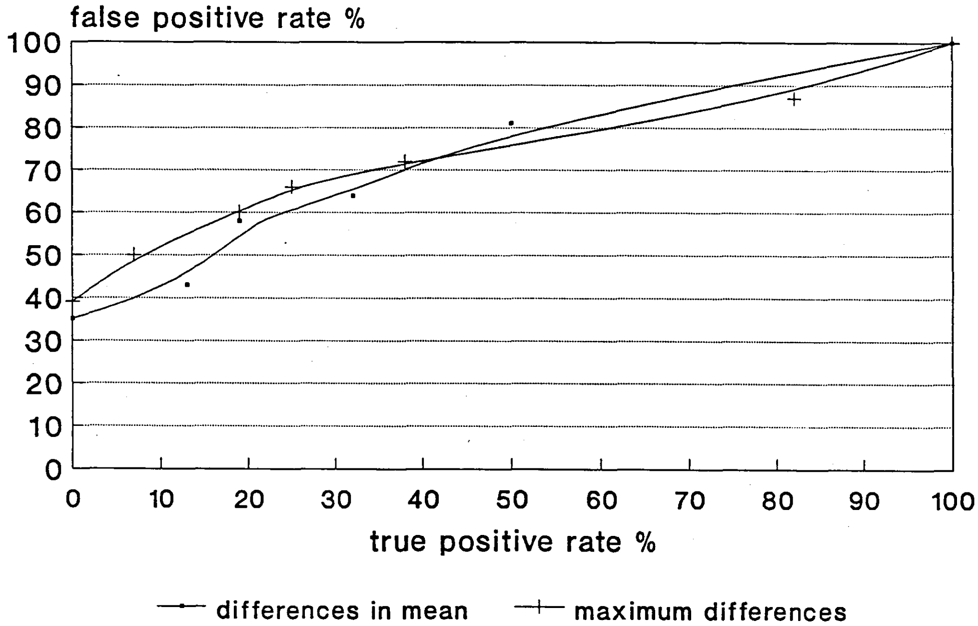


FIG. 6.11. A RECEIVER OPERATOR CURVE (TRUE POSITIVE RATE AGAINST FALSE POSITIVE RATE) WHICH DEMONSTRATES THE DETECTION RATE OF SUPERFICIAL DIGITAL FLEXOR TENDON INJURY USING THE DIFFERENCE IN MEAN TEMPERATURE AND MAXIMUM TEMPERATURE DIFFERENCE AS SEPARATOR VARIABLES AT VARIOUS POSITIVITY CRITERIA IN 48 THERMOGRAPHIC EXAMINATIONS OF 28 HORSES WITH ACUTE SUPERFICIAL DIGITAL FLEXOR TENDON INJURY (GROUP 6.3) AND 16 THERMOGRAPHIC EXAMINATIONS RECORDED FROM NORMAL HORSES (GROUP 6.1).

MAXIMUM DIFFERENCES	MEAN °C	SENSITIVITY (%)	SPECIFICITY (%)
1	1	77	56
1	2	75	56
1	3	64	75
1	4	62	75
1	5	54	87
1	6	47	93
1	7	39	100
2	1	66	68
2	2	64	68
2	3	60	75
2	4	58	75
2	5	58	81
2	6	47	93
2	7	39	100
3	1	56	81
3	2	56	81
3	3	56	81
3	4	56	81
3	5	56	81
3	6	47	93
3	7	39	100
4	1	44	87
4	2	44	87
4	3	44	87
4	4	44	87
4	5	44	87
4	6	44	93
4	7	35	100
5	1	33	100
5	1	33	100

TABLE 6.6. THE SENSITIVITY AND THE SPECIFICITY OF MICROWAVE THERMOGRAPHIC EXAMINATION USING A COMBINATION OF THE DIFFERENCE IN MEAN TEMPERATURE AND MAXIMUM TEMPERATURE DIFFERENCE AS THE SEPARATOR VARIABLE WITH VARIOUS POSITIVITY CRITERIA IN 48 THERMOGRAPHIC EXAMINATIONS OF 28 HORSES WITH ACUTE SUPERFICIAL DIGITAL FLEXOR TENDON INJURY (GROUP 6.3) AND 16 THERMOGRAPHIC EXAMINATIONS RECORDED FROM NORMAL HORSES (GROUP 6.1).

MAXIMUM DIFFERENCES	MEAN °C	SENSITIVITY (%)	SPECIFICITY (%)
1	1	77	56
1	2	66	68
1	3	56	81
1	4	44	87
1	5	33	100
2	1	75	56
2	2	64	68
2	3	56	81
2	4	44	87
2	5	33	100
3	1	64	75
3	2	60	75
3	3	56	81
3	4	44	87
3	5	33	100
4	1	62	75
4	2	58	75
4	3	56	81
4	4	44	87
4	5	33	100
5	1	58	81
5	2	58	81
5	3	56	81
5	4	44	87
5	5	33	100
6	1	47	93
6	2	47	93
6	3	47	93
6	4	44	93
6	5	33	100
7	1	39	100
7	4	35	100
7	5	29	100
7	7	18	100
7	12	0	100

TABLE 6.7. THE SENSITIVITY AND THE SPECIFICITY OF MICROWAVE THERMOGRAPHIC EXAMINATION USING A COMBINATION OF THE DIFFERENCE IN MEAN TEMPERATURE AND MAXIMUM TEMPERATURE DIFFERENCE AS THE SEPARATOR VARIABLE WITH VARIOUS POSITIVITY CRITERIA IN 48 THERMOGRAPHIC EXAMINATIONS OF 28 HORSES WITH ACUTE SUPERFICIAL DIGITAL FLEXOR TENDON INJURY (GROUP 6.3) AND 16 THERMOGRAPHIC EXAMINATIONS RECORDED FROM NORMAL HORSES (GROUP 6.1).

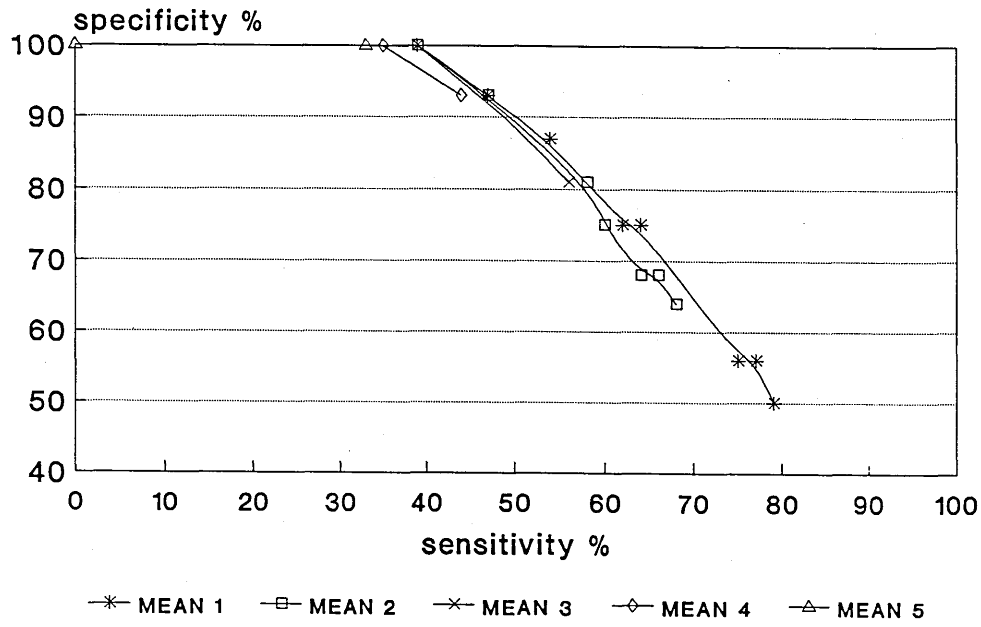


FIG. 6.12. THE CURVES OF THE SENSITIVITY AGAINST THE SPECIFICITY OF MICROWAVE THERMOGRAPHIC EXAMINATION USING COMBINATIONS OF THE DIFFERENCE IN MEAN TEMPERATURE AND A VARIETY OF MAXIMUM TEMPERATURE DIFFERENCES AS THE SEPARATOR VARIABLES IN 48 THERMOGRAPHIC EXAMINATIONS OF 28 HORSES WITH ACUTE SUPERFICIAL DIGITAL FLEXOR TENDON INJURY (GROUP 6.3) AND 16 THERMOGRAPHIC EXAMINATIONS RECORDED FROM NORMAL HORSES (GROUP 6.1).

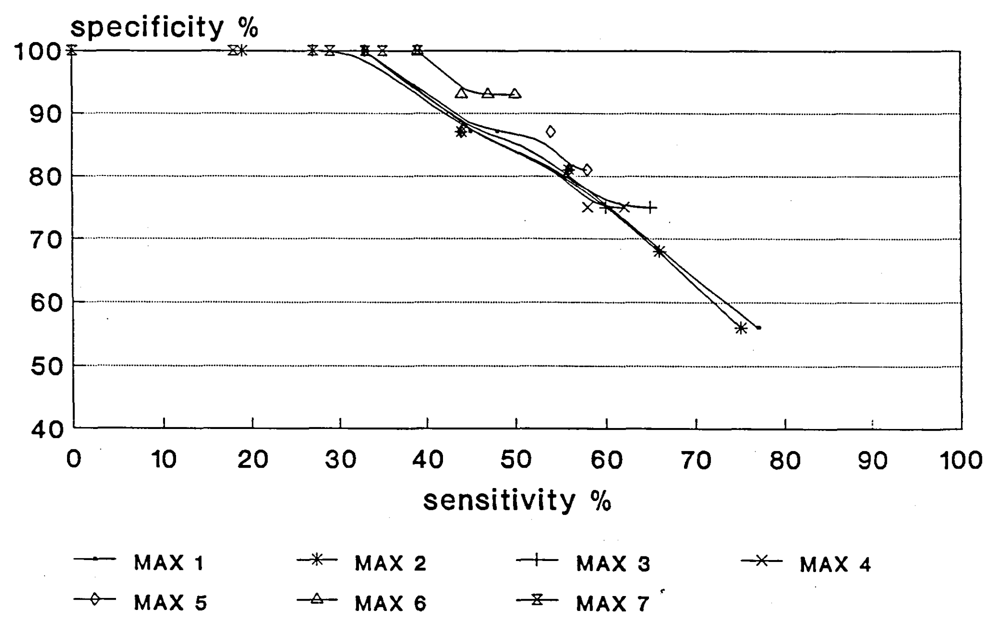


FIG. 6.13. THE CURVE OF THE SENSITIVITY AGAINST THE SPECIFICITY OF MICROWAVE THERMOGRAPHIC EXAMINATION USING COMBINATIONS OF THE MAXIMUM TEMPERATURE DIFFERENCE AND A VARIETY OF DIFFERENCES IN MEAN TEMPERATURE AS THE SEPARATOR VARIABLES IN 48 THERMOGRAPHIC EXAMINATIONS OF 28 HORSES WITH ACUTE SUPERFICIAL DIGITAL FLEXOR TENDON INJURY (GROUP 6.3) AND 16 THERMOGRAPHIC EXAMINATIONS RECORDED FROM NORMAL HORSES (GROUP 6.1).

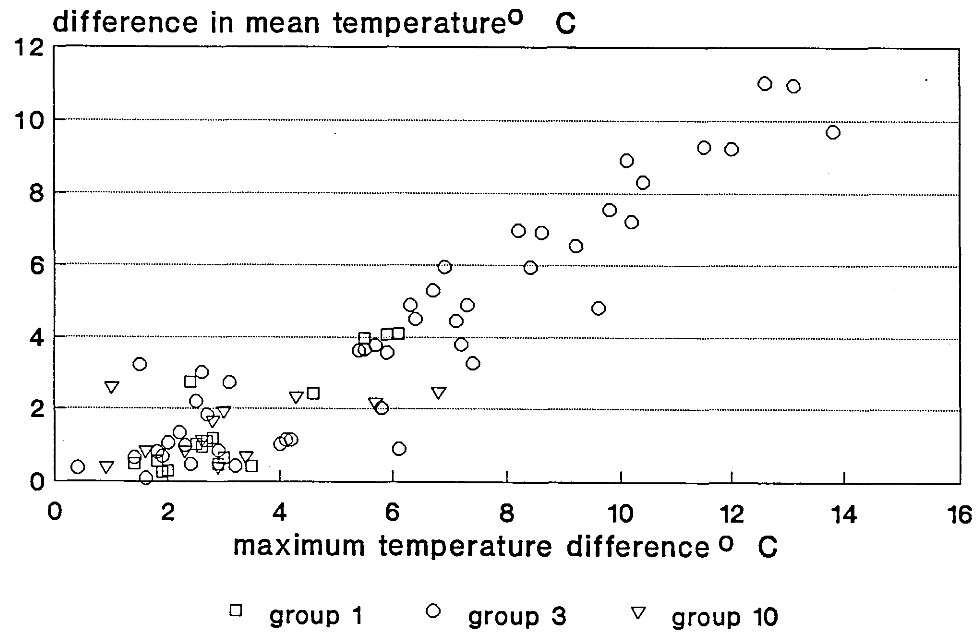


FIG. 6.14. THE PLOT OF DIFFERENCES IN THE MEAN TEMPERATURE AND MAXIMUM TEMPERATURE DIFFERENCE RECORDED IN 48 THERMOGRAPHIC EXAMINATIONS OF 28 HORSES WITH ACUTE SUPERFICIAL DIGITAL FLEXOR TENDON INJURY (GROUP 6.3) AND 16 THERMOGRAPHIC EXAMINATIONS RECORDED FROM NORMAL HORSES (GROUP 6.1) AND 12 MICROWAVE THERMOGRAPHIC EXAMINATIONS RECORDED FROM HORSES WITH SOFT TISSUE INJURIES IN THE METACARPAL REGION (GROUP 6.10).

most of the thermographs from group 6.10 (9/12), and many of the thermographs from the normal animals, had mean temperature differences below 2.89^{o}C. The majority had maximum temperature differences below 5.33^{o}C, which was the upper limit of normal defined in Section 6.1.1.

On the basis of these results, a number of criteria were identified which were potentially useful diagnostic parameters which were: 1. a temperature profile of C or D irrespective of the mean and maximum temperature differences; 2. a mean temperature difference of greater than 2.89^{o}C and/or a maximum temperature difference of greater than 5.33^{o}C irrespective of temperature profile; 3. a temperature profile of C, or D, and/or a mean temperature difference of greater than 2.89^{o}C and/or a maximum temperature difference of greater than 5.33^{o}C; 4. a temperature profile of C, or D, and/or a mean temperature difference of greater than 2.89^{o}C and/or a maximum temperature difference of greater than 5.33^{o}C and/or a mean temperature of the contralateral limb which was outwith the normal range.

The use of all four criteria was the most successful combination in acute tendon injuries (Table 6.8). Use of the mean and maximum temperature differences improved the sensitivity, while reducing the specificity and use of a mean temperature of the contralateral limb of less than 25.04^{o}C, improved the sensitivity without affecting the specificity markedly.

TABLE 6.8. THE SENSITIVITY AND SPECIFICITY OF MICROWAVE THERMOGRAPHIC EXAMINATION USING A VARIETY OF PARAMETERS AS SEPARATOR VARIABLES IN 210 EXAMINATIONS OF 56 HORSES WITH ACUTE SUPERFICIAL DIGITAL FLEXOR TENDON INJURY (GROUPS 6.3 - 6.9), 16 THERMOGRAPHIC EXAMINATIONS RECORDED FROM NORMAL HORSES (GROUP 6.1) AND 12 MICROWAVE THERMOGRAPHIC EXAMINATIONS RECORDED FROM HORSES WITH SOFT TISSUE INJURIES IN THE METACARPAL REGION (GROUP 6.10).

DISEASED POPULATIONS.

1. = 48 EXAMINATIONS WITH 60 INJURED S.D.F.T. OF LESS THAN FOUR WEEKS DURATION (GROUP 6.3).

2. = 41 EXAMINATIONS WITH 63 INJURED S.D.F.T. OF FIVE TO EIGHT WEEKS DURATION (GROUP 6.4).

3. = 18 EXAMINATIONS WITH 25 INJURED S.D.F.T. OF NINE TO TWELVE WEEKS DURATION (GROUP 6.5).

4. = 13 EXAMINATIONS WITH 20 INJURED S.D.F.T. OF THIRTEEN TO SIXTEEN WEEKS DURATION (GROUP 6.6).

5. = 17 EXAMINATIONS OF 24 INJURED S.D.F.T. OF SEVENTEEN TO 28 WEEKS DURATION (GROUP 6.7).

6. = 23 EXAMINATIONS OF 29 INJURED S.D.F.T. OF TWENTY NINE TO FIFTY TWO WEEKS DURATION (GROUP 6.8).

7. = 29 EXAMINATIONS OF 39 INJURED S.D.F.T. OF GREATER THAN FIFTY TWO WEEKS DURATION (GROUP 6.9).

NORMAL POPULATIONS

= 16 CLINICALLY HORSES WITH NORMAL S.D.F.T. CONFIRMED ON ULTRASONOGRAPHIC EXAMINATION.

\+ 11 HORSES WITH UNILATERAL SOFT TISSUE INJURIES OF THE METACARPAL REGION WITH NORMAL S.D.F.T. CONFIRMED ON ULTRASONOGRAPHIC EXAMINATION.

\+ 61 HORSES WITH CLINICALLY NORMAL S.D.F.T.

\+ THE REMAINING LIMBS FROM THE DISEASED POPULATIONS WITH NORMAL S.D.F.T. CONFIRMED ON ULTRASONOGRAPHIC EXAMINATION.

I.E. 1. = 36
2. = 19
3. = 11
4. = 6
5. = 10
6. = 17
7. = 19

CRITERIA	SENSITIVITY (%)	SPECIFICITY (%)
POPULATION 1		
PROFILE ONLY	76	89
MEAN > 2.89°C AND/OR MAX > 5.33°C ONLY	53	93
PROFILE AND/OR MEAN > 2.89°C AND/OR MAX > 5.33°C	78	86
PROFILE AND/OR MEAN > 2.89°C AND/OR MAX > 5.33°C AND/OR CONTRALATERAL. MEAN < 25.04°C	80	86
POPULATION 2		
PROFILE ONLY	55	91
PROFILE AND/OR MEAN > 2.89°C AND/OR MAX > 5.33°C	61	87
PROFILE AND/OR MEAN > 2.89°C AND/OR MAX > 5.33°C AND/OR CONTRALATERAL. MEAN < 25.04°C	74	86
POPULATION 3		
PROFILE ONLY	64	89
PROFILE AND/OR MEAN > 2.89°C AND/OR MAX > 5.33°C	68	84
PROFILE AND/OR MEAN > 2.89°C AND/OR MAX > 5.33°C AND/OR CONTRALATERAL. MEAN < 25.04°C	68	84
POPULATION 4		
PROFILE ONLY	40	90
PROFILE AND/OR MEAN > 2.89°C AND/OR MAX > 5.33°C	55	84
PROFILE AND/OR MEAN > 2.89°C AND/OR MAX > 5.33°C AND/OR CONTRALATERAL. MEAN < 25.04°C	65	84
POPULATION 5		
PROFILE ONLY	41	90
PROFILE AND/OR MEAN > 2.89°C AND/OR MAX > 5.33°C	45	85
PROFILE AND/OR MEAN > 2.89°C AND/OR MAX > 5.33°C AND/OR CONTRALATERAL. MEAN < 25.04°C	54	85
POPULATION 6		
PROFILE ONLY	48	91
PROFILE AND/OR MEAN > 2.89°C AND/OR MAX > 5.33°C	51	87
PROFILE AND/OR MEAN > 2.89°C AND/OR MAX > 5.33°C AND/OR CONTRALATERAL. MEAN < 25.04°C	58	87
POPULATION 7		
PROFILE ONLY	20	95
PROFILE AND/OR MEAN > 2.89°C AND/OR MAX > 5.33°C	25	87
PROFILE AND/OR MEAN > 2.89°C AND/OR MAX > 5.33°C AND/OR CONTRALATERAL. MEAN < 25.04°C	30	85

PART 6.3. A STUDY ON THE USE OF MICROWAVE THERMOGRAPHY FOR THE DETECTION OF SUBCLINICAL DIGITAL FLEXOR TENDON INJURY IN THE HORSE.

SECTION 6.3.1. MATERIALS AND METHODS.

Animals.

A group of thirty-four horses in training were included in the study. There were twenty-six geldings and the remainder were mares. Their ages ranged from four to seven years old. The study was performed during the months October to December, 1988. Examinations were performed on weeks 1, 2, 3, 4, 5, 8, 10, 11, 12 and 13. The animals were not all available for examination on each occasion due to factors related to their management.

Thermographic Examination.

Thermographic examination was performed using a microwave thermography unit as described in Section 6.1.1.

Evaluation Of Thermographs.

The mean temperature for each thermograph and standard deviations were calculated, and the maximum temperature difference between the contralateral limbs was determined. Thermographs recorded from ten horses which remained clinically normal throughout the study period were used to calculate the mean and standard deviation of the mean temperature of the group. The remainder of the thermographs were assessed to determine if they were outwith two standard deviations of the mean. The temperature at each location was plotted and the temperature profile was evaluated and classified using the criteria described in Part 6.1.

The thermographs were classified as normal if they had temperature profiles A, B or E, there was a mean temperature difference between limbs of less than 2.89^{o}C, a maximum temperature difference between contralateral points of less than 5.33^{o}C and if the mean temperature of the contralateral limb was within the normal range calculated for the group.

Clinical Details.

Information was obtained retrospectively each week from the trainer and his veterinary surgeon on the clinical history of these cases. In particular, the presence of lameness, soft tissue swelling and skin disease in the limbs were recorded. In those cases in which there was clinical evidence of tendon injury, ultrasonographic examination was performed to confirm its existence. The investigation of other veterinary problems was performed by the trainer's veterinary surgeon.

Mathematical Analysis.

The sensitivity and specificity of the technique were calculated for various combinations of separator variables. These were: 1. a temperature profile of C, D or F irrespective of the mean and maximum temperature differences; 2. a mean temperature difference of greater than 2.89^{o}C and/or a maximum temperature difference of greater than 5.33^{o}C irrespective of temperature profile; 3. a temperature profile of C, D or F, and/or a mean

temperature difference of greater than 2.89°C and/or a maximum temperature difference of greater than 5.33°C;
4. a temperature profile of C, D or F, and/or a mean temperature difference of greater than 2.89°C and/or a maximum temperature difference of greater than 5.33°C and/or a mean temperature of the contralateral limb which was outwith the normal range.

The definition of true positive was the diagnosis of acute superficial digital flexor tendon injury within two weeks of the recording of the thermograph. The sensitivity and specificity were calculated for the individual horses and for each individual thermograph.

SECTION 6.3.2: RESULTS.

Thermographs were recorded from 420 limbs, ranging from four to twenty per animal, and the details of these are recorded in Appendix 6.11.

The mean temperature recorded in ten horses was 31.23°C, standard deviation 3.05°C and, therefore the 25.12 - 37.34°C was taken as the normal range. None of the thermographs recorded from the remaining horses exceeded this range but, there were 17 observations below this range in ten horses.

The distribution of the mean temperatures recorded is illustrated in Fig. 6.15, the mean limb temperature recorded in individual animals varied weekly as did the temperature profiles. The temperature profiles were distributed in the following way: A: 195, 46%; B: 144, 34%; C: 15, 3%; D: 4, 1%; E: 41, 9%; F: 21, 5%. Abnormal

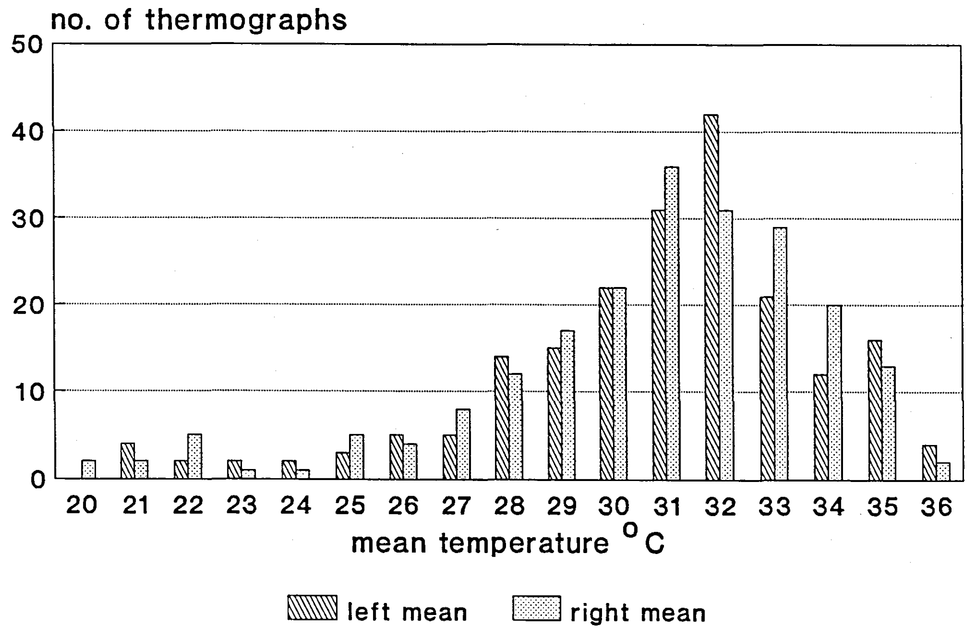


FIG. 6.15. THE FREQUENCY OF OBSERVATION OF EACH MEAN TEMPERATURE IN 420 MICROWAVE THERMOGRAPHS RECORDED FROM THE LIMBS OF THIRTY FOUR HORSES IN TRAINING.

results were observed in 45 thermographs, in 57 limbs and in 18 horses and the details of these are listed in Table 6.9. Profile C was observed in 11 horses, profile D in four horses and profile F in seven horses.

The maximum temperature difference between limbs exceeded 5.33°C in 10 thermographs and in seven horses and in nine of these thermographs in six of the horses a mean temperature difference of greater than 2.89°C was also noted and the distribution of the difference in mean temperature and the maximum temperature difference is illustrated in Figs 6.16 and 6.17.

Two horses sustained superficial digital flexor tendon injury during the trial, Nos. 6.14 (right fore) and 6.34 (left fore). Thereafter, thermographs from these cases were excluded from the study. Both of these animals demonstrated thermographic abnormalities prior to the detection of clinical signs of tendon injury (Figs. 6.18 and 6.19).

Horse 6.27 had chronic tendinitis in both forelimbs of approximately fifteen months' duration: it frequently displayed thermographic abnormalities but these were not consistent findings. There was no incident of acute tendon injury during the study period although three weeks after completion of the study the horse sustained a recurrence of tendon injury. Nevertheless, for the purposes of the statistical analysis this animal was regarded as having no tendon injury.

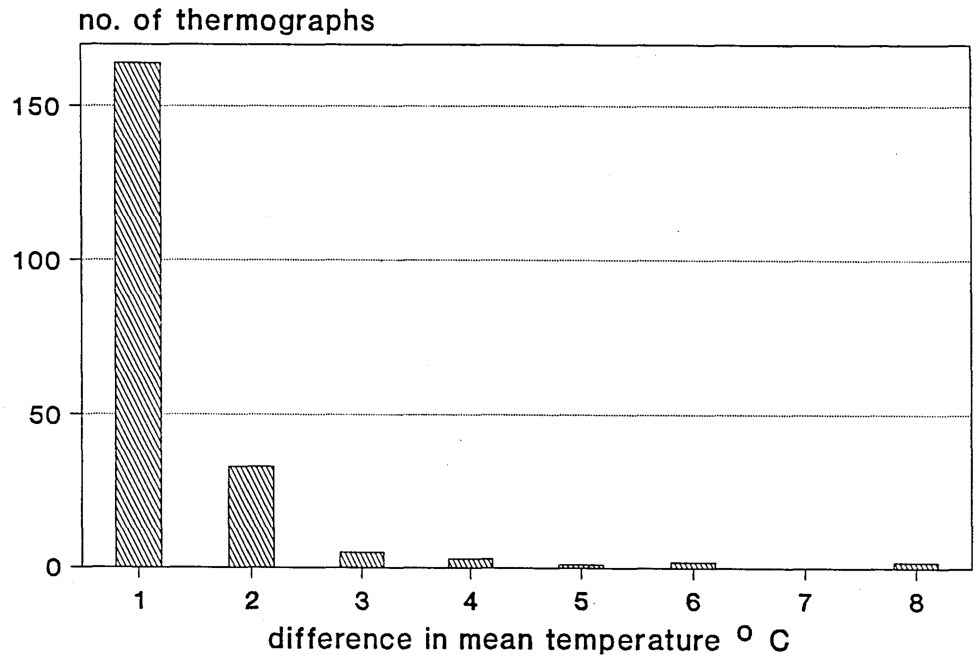


FIG. 6.16. THE FREQUENCY OF OBSERVATION OF EACH DIFFERENCE IN MEAN TEMPERATURE IN 420 MICROWAVE THERMOGRAPHS RECORDED FROM THE THIRTY FOUR HORSES IN TRAINING.

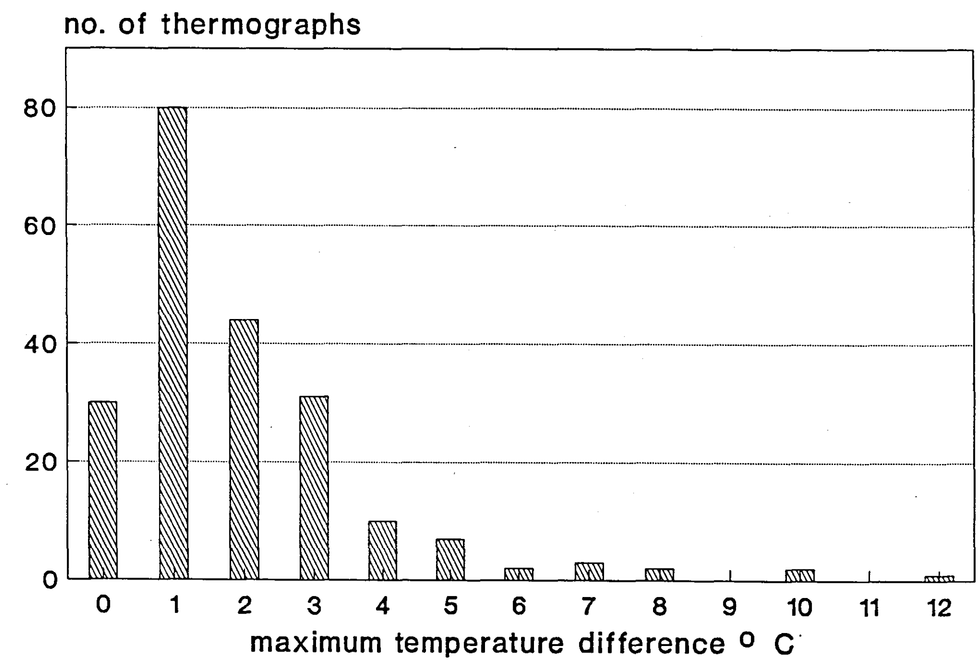


FIG. 6.17. THE FREQUENCY OF OBSERVATION OF EACH MAXIMUM TEMPERATURE DIFFERENCE BETWEEN BILATERALLY SYMMETRICAL POINTS IN 420 MICROWAVE THERMOGRAPHS RECORDED FROM THIRTY FOUR HORSES IN TRAINING.

TABLE 6.9. MICROWAVE THERMOGRAPHIC ABNORMALITIES RECORDED FROM THIRTY-FOUR HORSES IN TRAINING OVER A THIRTEEN WEEK PERIOD.

* left is listed first where both given
left mean = mean temperature of the left fore limb
right mean = mean temperature of the right fore limb
mean diff = the difference in the mean temperature of the fore limbs
max diff = the maximum difference in temperature of the fore limbs between fore limbs

CASE NO.	WEEK	LIMB AFFECTED	MEAN LEFT (°C)	MEAN RIGHT (oC)	MEAN DIFF (°C)	MAX DIFF (°C)	PROFILE*
6.1	8	BOTH	22.19	20.67	1.69	2.90	B,B
	4	LEFT	33.49	33.20	0.29	1.90	C
6.2	2	LEFT	32.25	32.70	0.45	2.60	C,F
6.4	12	BOTH	21.67	22.01	0.34	4.70	B,B
6.5	5	BOTH	29.06	27.99	1.07	3.50	F
6.8	3	LEFT	35.30	35.60	0.30	1.90	D
	5	BOTH	29.70	31.00	1.30	3.60	C
6.11	1	LEFT	28.19	25.10	3.09	7.00	B
6.14	3	RIGHT	35.30	34.56	0.74	1.60	C
	4	BOTH	33.19	34.13	0.94	1.30	C,C
6.15	2	LEFT	28.50	26.05	1.45	6.80	A,A
	8	LEFT	32.90	32.30	0.60	2.40	F
	12	LEFT	27.57	20.09	7.48	12.20	B
6.17	12	RIGHT	23.20	28.11	4.91	10.70	C
6.18	4	LEFT	32.91	32.26	0.65	1.70	C
	5	BOTH	21.96	23.93	1.96	5.30	B,B
	8	BOTH	21.30	21.87	0.57	2.20	B,B
6.20	1	BOTH	31.92	31.30	0.62	3.30	D,F
	2	RIGHT	32.83	32.63	0.20	0.40	F
	12	RIGHT	30.02	31.20	1.18	5.20	C
	13	RIGHT	30.08	31.03	0.95	3.50	F
6.21	12	BOTH	21.98	22.68	0.70	5.20	B,B
6.23	11	LEFT	31.76	29.43	3.39	5.50	A
	12	LEFT	32.59	29.43	3.16	6.30	B
6.24	3	LEFT	35.63	35.09	0.54	1.70	F
	4	BOTH	33.83	33.79	0.04	1.40	C,F
6.25	5	BOTH	33.26	32.87	0.39	1.90	F,F
6.26	3	LEFT	34.86	34.47	1.06	1.70	F
	5	LEFT	30.20	29.87	0.33	3.10	F
	8	RIGHT	30.02	29.83	0.19	3.40	F
	12	LEFT	30.85	30.06	1.33	3.00	F
6.27	2	LEFT	34.84	35.80	0.96	3.20	D
	5	LEFT	32.21	31.69	0.65	1.80	F
	8	BOTH	32.09	31.56	0.53	4.10	F,C
	12	RIGHT	31.99	32.07	0.80	1.40	F
6.28	1	BOTH	23.16	22.48	0.68	4.30	B,B
	12	BOTH	22.96	21.90	1.06	3.80	B,B
6.29	1	RIGHT	32.51	31.92	0.59	1.40	D
	3	RIGHT	31.49	35.30	3.81	7.10	C
6.31	5	LEFT	34.24	32.71	1.53	2.50	C
6.32	4	RIGHT	34.41	33.92	0.49	1.10	F
6.33	4	RIGHT	27.73	33.23	5.50	8.60	B
	5	RIGHT	29.87	22.54	7.33	10.10	A
6.34	2	LEFT	31.97	26.62	5.35	7.80	E
	3	LEFT	35.24	34.83	0.41	1.20	C

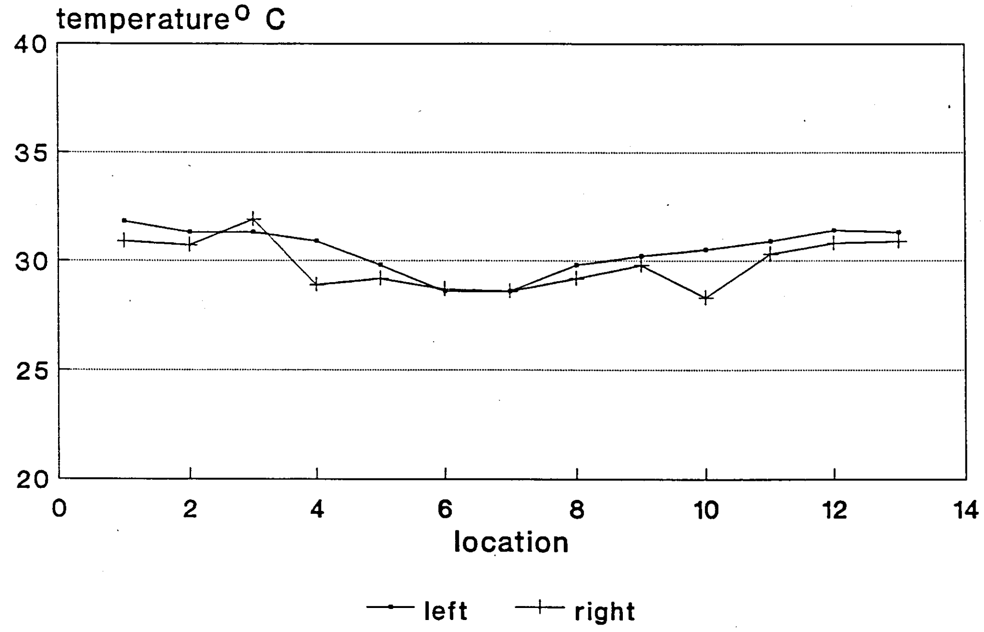


FIG. 6.18.a. A NORMAL MICROWAVE THERMOGRAPH RECORDED FROM HORSE 6.3.14. ON WEEK ONE OF THE STUDY : BOTH LIMBS DISPLAY THE NORMAL TEMPERATURE PROFILE B.

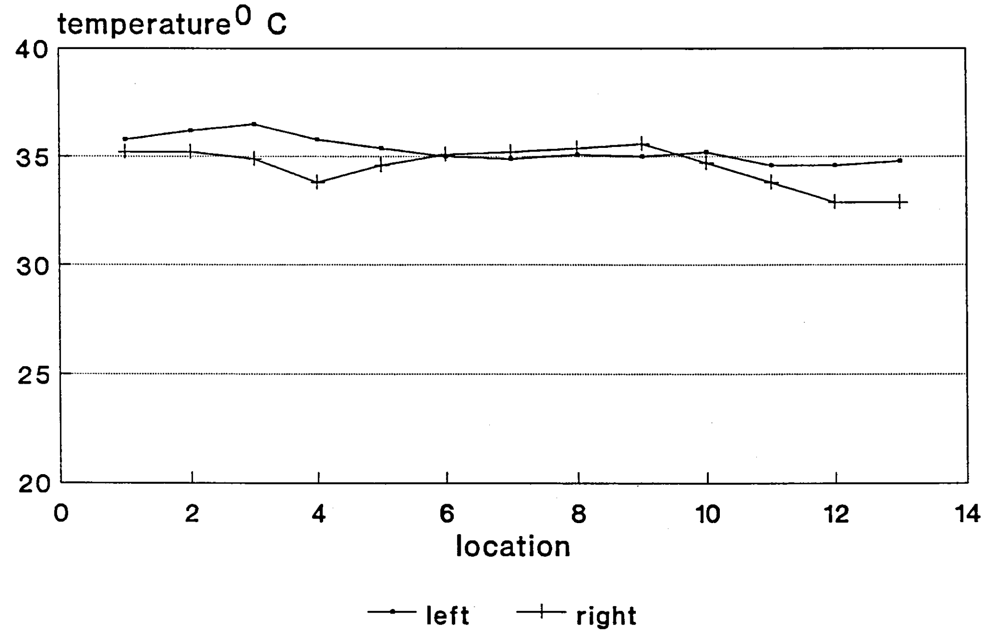


FIG. 6.18.b. AN ABNORMAL MICROWAVE THERMOGRAPH RECORDED FROM HORSE 6.3.14. ON WEEK THREE OF THE STUDY : THE RIGHT LIMB HAS TEMPERATURE PROFILE C MANIFESTED BY AN INCREASE IN TEMPERATURE IN THE DISTAL THIRD OF THE METACARPAL REGION (LOCATIONS 7 - 10) BUT THE MAXIMUM TEMPERATURE DIFFERENCE BETWEEN LIMB AND THE DIFFERENCE IN MEAN TEMPERATURE ARE WITHIN NORMAL LIMITS (1.6°C AND 0.74°C RESPECTIVELY).

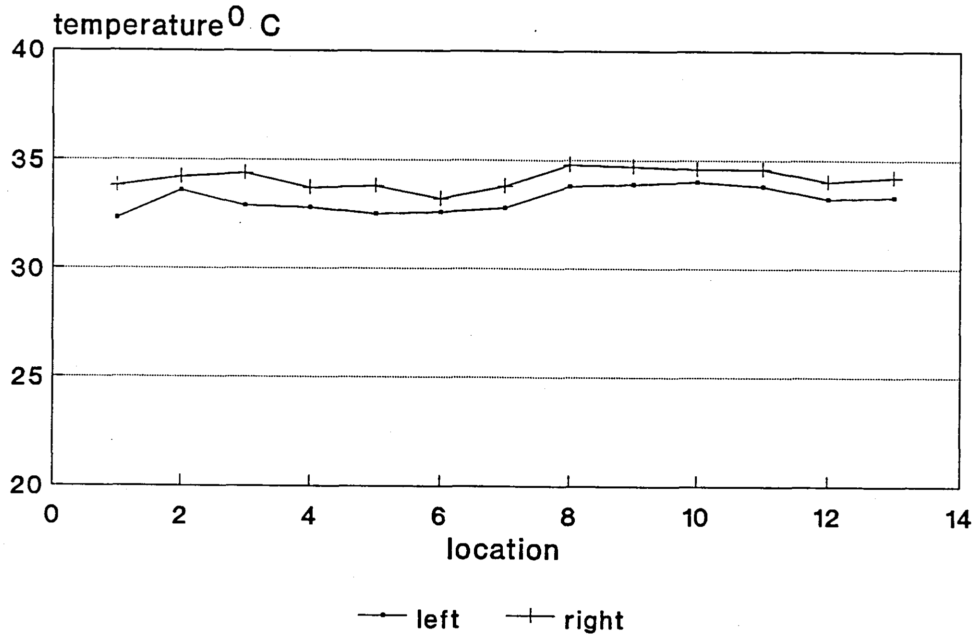


FIG. 6.18.c. AN ABNORMAL MICROWAVE THERMOGRAPH RECORDED FROM HORSE 6.3.14. ON WEEK FOUR OF THE STUDY : BOTH LIMBS HAVE ABNORMAL TEMPERATURE PROFILE C BUT THE MAXIMUM TEMPERATURE DIFFERENCE BETWEEN LIMB AND THE DIFFERENCE IN MEAN TEMPERATURE ARE WITHIN NORMAL LIMITS (1.3oC AND 0.94oC RESPECTIVELY).

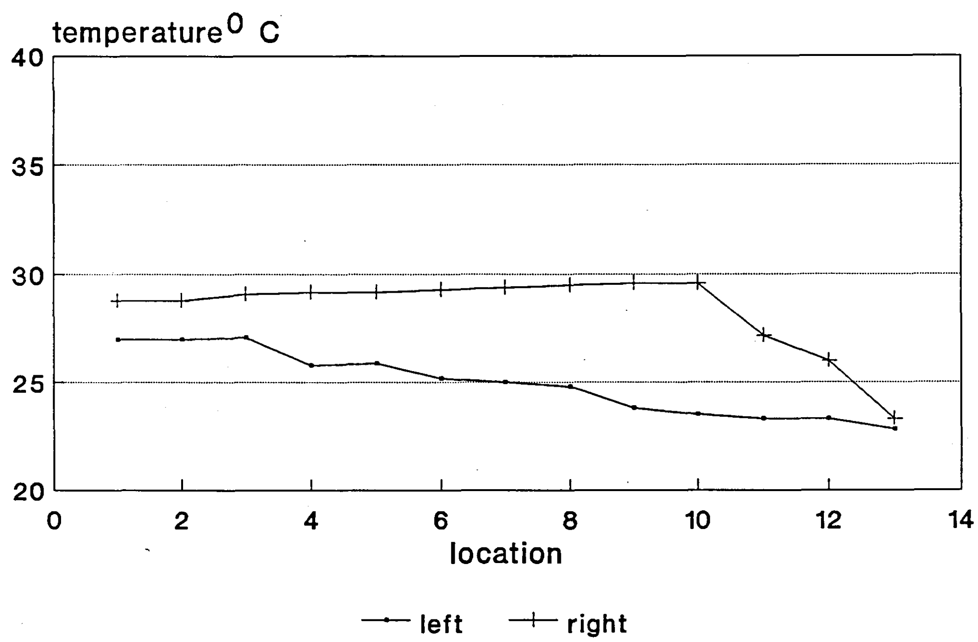


FIG. 6.18.d. AN ABNORMAL MICROWAVE THERMOGRAPH RECORDED FROM HORSE 6.3.14. ON WEEK FIVE OF THE STUDY, 3 DAYS AFTER CLINICAL SIGNS OF SUPERFICIAL DIGITAL FLEXOR TENDON INJURY WERE APPRECIATED: THE TEMPERATURE OF THE RIGHT LIMB IS ELEVATED THROUGHOUT THE METACARPAL REGION PRODUCING TEMPERATURE PROFILE C.

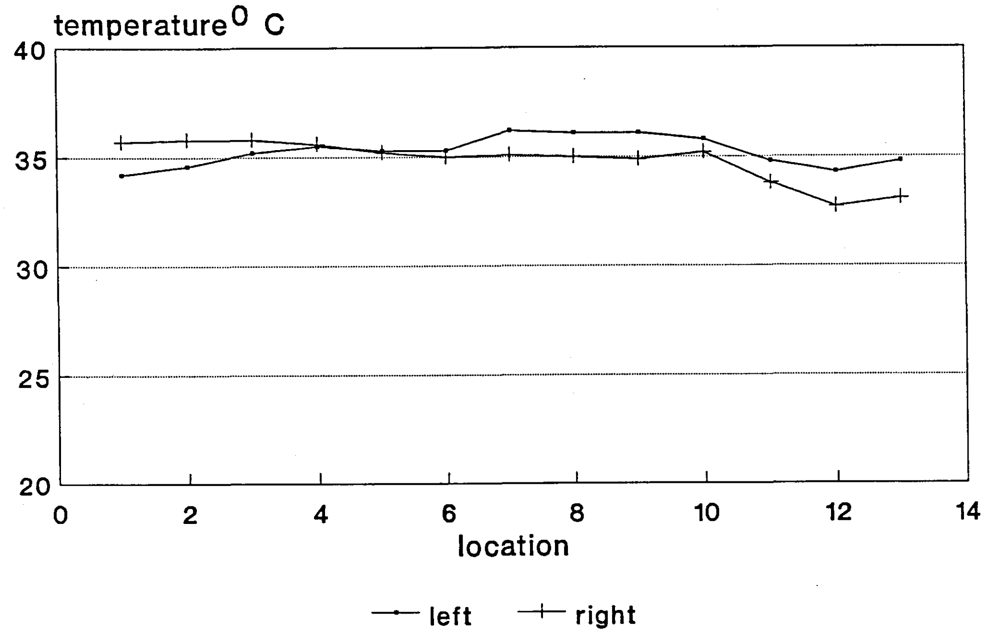


FIG. 6.19.a. AN ABNORMAL MICROWAVE THERMOGRAPH RECORDED FROM HORSE 6.3.34. ON WEEK TWO OF THE STUDY: THE LEFT LIMB HAS A NORMAL TEMPERATURE PROFILE (E) BUT THE DIFFERENCE IN MEAN TEMPERATURES IS 5.35 °C AND THE MAXIMUM DIFFERENCE IN TEMPERATURE BETWEEN LIMBS IS 7.8 °C.

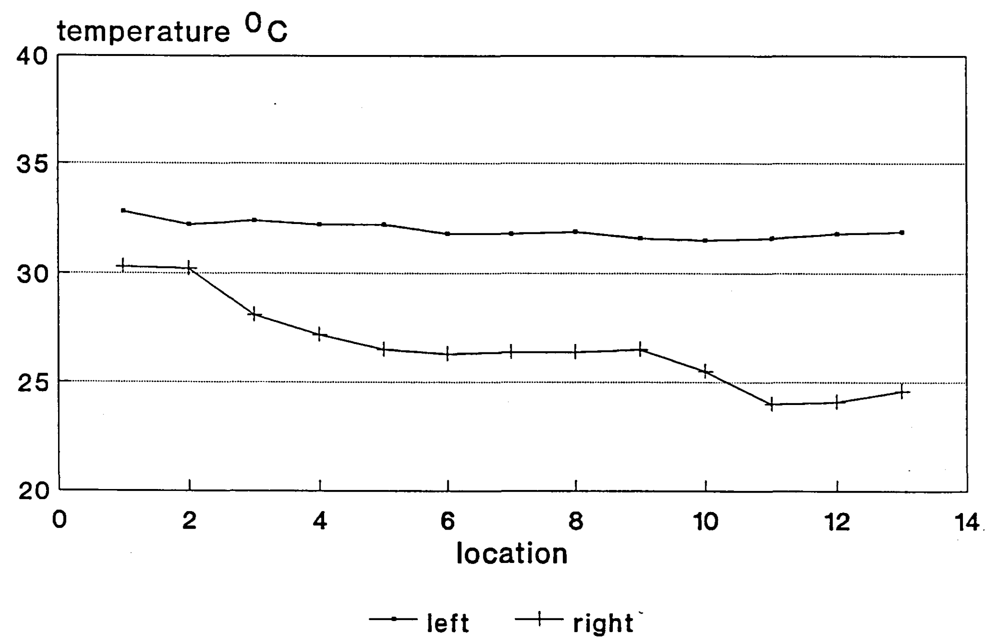


FIG. 6.19.b. AN ABNORMAL MICROWAVE THERMOGRAPH RECORDED FROM HORSE 6.3.34. ON WEEK THREE OF THE STUDY: THE LEFT LIMB DEMONSTRATES PROFILE C THE RIGHT LIMB HAS A HIGHER MEAN TEMPERATURE THAN THE PREVIOUS WEEK BUT THE TEMPERATURE PROFILE IS NORMAL (B).

In individual horses, using the criteria of a temperature profile of C, D or F, the sensitivity was 100% and specificity, 50%; a mean temperature difference of greater than 2.89^{o}C and/or a maximum temperature difference of greater than 5.33^{o}C produced a sensitivity of 50% and specificity of 81%; a temperature profile of C, D or F and/or a mean temperature difference of greater than 2.89^{o}C and/or a maximum temperature difference of greater than 5.33^{o}C was 100% sensitive but the specificity was reduced to 40% while the criteria of an abnormal temperature profile, and/or a mean temperature profile of greater than 2.89^{o}C and/or maximum temperature difference of greater than 5.33^{o}C and/or a mean temperature of the contralateral limb outwith the normal range produced a sensitivity of 100%, but reduced the specificity to 31%.

When the total number of thermographs were considered, there were four instances in which clinical disease followed within two weeks of obtaining the thermographs. Using the criteria of a temperature profile of C, D or F, irrespective of maximum temperature difference, the sensitivity was 75% and the specificity 92%, a mean temperature difference of greater than 2.89^{o}C and/or a maximum temperature difference of greater than 5^{o}C produced a sensitivity 25% and specificity 98%; a temperature profile of C, D or F, and/or a mean temperature difference of greater than 2.89^{o}C and/or a maximum temperature difference of greater than 5^{o}C increased the sensitivity to 100% and reduced the specificity to 90%; while the use of all four parameters maintained the sensitivity of 100% but reduced the specificity to 86%.

SECTION 6.4. DISCUSSION.

Infrared thermographic investigations of the equine limb have demonstrated that the warmest parts of the limb correspond with the distribution and location of the larger vessels and vasculature (Stromberg, 1971; Stromberg and Norberg, 1971; Turner, 1981). Studies comparing the infrared thermographic profile of the limb with the results of 133 Xe disappearance rate studies have established that the temperature is related to the tissue perfusion (Stromberg and Norberg, 1971). The normal infrared profile of the palmar metacarpal region has been described (Stromberg, 1971; Stromberg, 1973; Webbon, 1978a; Turner, 1981). The mid portion of the superficial digital flexor tendon is a relatively avascular area (Stromberg, 1971; Webbon, 1978b), and this region was the most commonly observed coldest point in infrared studies of the palmar metacarpal area (Stromberg, 1971; Stromberg, 1973, Webbon, 1978a).

In normal horses, Stromberg (1971, 1973) identified three distinct temperature patterns or profiles which he classified as Types I, II, and III. Type I was the most common and occurred in 77% of his study group. In these horses, a cold area was identified in the mid or distal regions of the superficial digital flexor tendon which was 1 to 3^{o}C below the remainder of the tendon. The temperature of the distal antebrachial region was generally 4 to 6^{o}C greater than the coldest point in the superficial digital flexor tendon and the volar aspect of the pastern was the coldest part of the distal limb.

Type II was observed in 16% of horses and was a similar pattern except that the cold spot in the mid or distal region was less than 1^{o}C colder than the remainder. This profile was usually bilateral.

The third profile, documented in that study, was a distally decreasing temperature, with a temperature range within the extremity of 2 to 6^{o}C. This profile was observed in 17 horses (7%) of the normal horses and the finding was bilateral in 14 of these individuals, although the contralateral limb displayed a different range in temperature. The remaining three horses had pattern III in one limb and pattern I in the other.

A study on infrared thermometery performed by Webbon, (1978b) utilised a system of five equidistant recordings from the level of the carpus to the level of the metacarpophalangeal joint. This report also demonstrated that the coldest region of the palmar metacarpal area was the mid or distal part of the tendon and that the majority of horses had a bilaterally symmetrical temperature distribution. Three normal temperature profiles were defined with which the individual thermometric studies could be described. These profiles differed slightly from those used by Stromberg (1971) in that while Stromberg's Type I and Type III were utilized, Type II was combined with Type I to form one classification. Webbon's (1978b) third classification was similar to Stromberg's Type I. It described the temperature distribution in which there was a cold area in the mid or distal part of the limb but in this variation the most proximal recording was colder than the second recording which was taken from the area of the proximal superficial digital flexor tendon. This pattern would also be classified as Type I using Stromberg's criteria because it contained a cold area in the mid region of the superficial digital flexor tendon. Using the thermometry technique, 31 out of 242 limbs in that study could not be categorised into any of the three normal temperature profiles defined by the author (Webbon, 1978a).

Differences in microwave and infrared thermographic findings are to be expected due to the fact that the two systems are measuring the temperature of different area (Barrett, Myers and Sadowsky, 1980; Land, 1987a; Land, 1987b). Nevertheless, the design of the temperature profiles used to describe the microwave thermographs in this study was based on the system proposed by Stromberg (1971, 1973) and four temperature profiles which described the temperature distributions within the subcutaneous tissues were identified in the two groups of normal horses in this study (Table 6.1). Profile A (Fig. 6.5) was similar to Stromberg's Type I and profile B (Fig. 6.6) was similar to Stromberg's Type III. Profile E (Fig. 6.8) was similar to Stromberg's Type II while profile C (Fig. 6.7) was similar to that described in association with acute superficial digital flexor tendon injury (Stromberg, 1971; Stromberg, 1972). A similar temperature profile was reported by Webbon (1978) as being a consistent finding in one horse with apparently normal flexor tendons but which had degenerative joint disease of the metacarpophalangeal joint.

In general terms, the frequency of observation of the various microwave thermographic temperature profiles was similar to that which has been described for infrared thermography. Profile A (Fig. 6.5) was the most frequently observed type in this study but it occurred only marginally more frequently than profile B (Fig. 6.6, Table 6.2). Whereas, in infrared thermography, it was observed more frequently (Stromberg, 1971; Stromberg, 1973; Webbon, 1978a).

Profile C (Fig. 6.7) was regarded as an abnormal finding on the basis of previous reports (Stromberg, 1971; Webbon, 1978a). However, no clinical signs were detected in those individuals in groups 6.1 and 6.2 in which it was observed. The clinical examinations were limited in that they consisted of an assessment of gait at the walk and trot and inspection of the limb for palpable signs of heat or swelling. In two of the four limbs in which Profile C was observed, ultrasonographic examination was performed and it indicated that the superficial digital flexor tendon was normal. More exhaustive investigation in these individuals may have produced evidence of some pathological process elsewhere in these limbs.

Profile E (Fig. 6.8) was an uncommon observation occurring in only 3.8% of microwave thermographs from normal horses. It was observed in 7% of Stromberg's cases and in those horses it was associated with ambient temperatures of greater than 20^{o}C (Table 6.2). The effect of ambient temperature on the microwave thermographic findings was not investigated as there were good theoretical grounds for believing that it did not influence the microwave thermographic findings to the extent occurring with infrared thermography (Land, 1987a; Stallard and others, 1987). However, in view of the wide range of temperature to which the average horse is exposed it may be that such a study would be warranted.

The microwave thermographic profiles did not exhibit as high a level of bilateral temperature profile symmetry as reported for infrared studies (Stromberg, 1971; Webbon, 1978a) and it would seem that the deep body temperature distribution is not as consistent.

The range in mean temperature of each limb was similar to that reported previously (Palmer, 1981). The mean temperatures of the thermographs recorded from group 6.1 were lower than those recorded from group 6.2. The most obvious reason for this was that the hair was removed in group 6.1 but not in group 6.2 but, alternatively this may reflect the differences in these horses exercise regimens. These points are discussed in more detail below.

The maximum differences between bilaterally symmetrical points were recorded and the mean value was 2.33^{o}C (Table 6.1). Again, this varies from that observed with infrared thermography in which only 4.3% of recordings demonstrated a bilateral difference of greater than 1^{o}C (Webbon, 1978a). In this study, the normal range of the difference between limbs in the mean temperature was 0 - 2.89^{o}C (Table 6.1).

The thermographic examination was simple to perform and well tolerated by all the horses in the study. The time required to perform the study was around five to seven minutes in total. The printer attached to the unit was not utilised as it was found to be more convenient simply to read the temperature indicated on the digital display to an assistant who recorded the results or to use a dictaphone. The data could then be plotted at a later date using a standard graphics package on a portable computer.

This study produced no evidence that removal of the hair influenced either the results of microwave thermography significantly or the configuration of the temperature profile. The minor differences in the location of the minimum temperature points can be explained in part by the fact that the technique has poor spatial resolution and alteration in the precise location of each recording point would be expressed as minor changes in the temperature profile within the limb.

The data collected in Part 6.1.2 of this study indicated that there was a higher mean temperature recorded in those horses which were examined without removal of the hair and the reason for this difference is unclear. The accurate measurement of the intensity of the microwave emission from the body depends on the minimisation of the reflection at the skin surface which occurs because of the difference in impedance between the body and the air (Land, 1987b). Thus, direct contact is required and the design and structure of the aerial is such that it presents a similar impedance as that of the body (Land, 1987b). The effect of a layer of hair and a consequent layer of trapped air has not been investigated by thermal modelling in laboratory conditions. However, these studies indicate that the perceived temperature is higher in unclipped legs than in clipped ones although no statistically significant difference could be established in the controlled study (Part 6.1.2). Theoretically, one might expect that the presence of the hair would result in a greater difference in impedance and, therefore, greater reflection of microwaves back into the body so that they could not be detected by the microwave receiver. This would produce artificially low temperatures in unclipped legs but this did not appear to be the case. Equally, it seems remarkable that the removal of the hair coat could influence the true deep temperature of the limb as the thermographic examinations were performed immediately after removal of the hair.

Opinion as to whether it is necessary to remove hair prior to infrared examination is divided. The hair can effect the infrared emission because of its insulating properties (Turner and others, 1983). Stromberg (1971) stated that it was not necessary to remove the hair although some authors have reported that they experienced difficulty in obtaining consistent results unless the hair was removed (Delahanty and Georgi, 1965; Clark and Cena, 1977). In studies on horses before and after exercise, Turner (1981) demonstrated that at rest removal of the hair produced a $3^{o}C$ elevation in temperature but did not alter the overall temperature profile. Following exercise, the increases in temperature which were observed were similar in clipped and unclipped limbs (Turner, 1981). However, Turner (1981) concluded that it was not necessary to remove the hair to produce consistent results. The conclusion of this study was that it was not necessary to remove the hair coat, although slightly higher mean temperatures could be expected in horses examined with the hair present.

The thermal pattern is the basis of thermographic interpretation (Turner and others, 1986). Previous reports of the use of thermographic methods for the diagnosis of acute tendon injury in the horse (Stromberg, 1971, Stromberg, 1973; Palmer, 1981), and microwave thermographic studies in man, have used the temperature distribution or profile as the diagnostic criterion (Barrett, Myers and Sadowsky, 1980; Myers, Barrett and Sadowsky, 1980; Fraser and others, 1987; Stallard and others, 1987). However, some of these studies have also employed comparisons between symmetrical points on the corresponding part of the body (Stromberg, 1971; Stromberg, 1973; Barrett and others, 1980; Myers and others, 1980; Palmer, 1981). The relative inefficiency of using temperature profile alone to evaluate the microwave thermographs was demonstrated in the horses in group 6.3 (Tables 6.3 and 6.8, Population 1). The main aim of this study was to develop the optimum criteria by which to separate diseased from normal individuals and, therefore, several different parameters were investigated to assess their suitability. A population of animals with soft tissue injuries in the metacarpal region was included as it was anticipated that these conditions would also produce elevations in the temperature of that region and, therefore, reduce the sensitivity of the technique. Their inclusion would provide a more rigorous assessment of the diagnostic power of the instrument. Previous reports on the use of thermography in the horse have concentrated on the comparison of individuals with a specific disease or injury with the normal findings in the area of investigation (Stromberg, 1971; Turner, 1981, Turner and others, 1983; Vaden and others, 1980; Bowman and others, 1983). While this approach is useful in establishing the abnormal features of the disease in question, the diagnostic capability of the test is not really challenged.

Superficial digital flexor tendon injury is associated with localised elevation of temperature (Stromberg, 1971). This is the result of increased perfusion through existing vascular beds in the early phases of healing and, subsequently, it is associated with the proliferation of capillaries (Stromberg, 1971). Increased temperature has also been documented in the horse in association with a variety of other soft tissue and bone injuries (Delahanty and Georgi, 1965; Vaden and others, 1980; Turner, 1981; Bowman and others, 1983; Turner and others, 1983; Turner and others, 1986). However, areas of decreased temperature with a surrounding zone of elevated temperature have also been observed in association with early inflammatory lesions in the horse, and in man (Kliot and Birnbaum, 1965; Winsor, 1971; Turner, 1981).

Stromberg (1971) described the elevation in temperature associated with tendon injury as hot spots which were surrounded by zones of decreasing temperature, thus disrupting the normal temperature profile of the limb. This finding has been confirmed in later reports (Stromberg, 1973; Palmer, 1981). In this study, three abnormal temperature profiles incorporating localised elevations in temperature were observed in cases with acute tendon injury (C, D and F Figs. 6.7, 6.9 and 6.10). However, in a proportion of horses with acute tendon injury (group 6.3), the temperature profile was similar to those documented in normal horses and described in Part 6.1 (Groups 6.1 and 6.2, Tables 6.2 and 6.3). Further, similar abnormal profiles were occasionally observed in the normal contralateral limbs, in normal horses and in the group of horses with soft tissue injuries which did not affect the superficial flexor tendon (group 6.10, Table 6.3). The significance of profile F was uncertain: it was not observed in the study on normal horses (Part 6.1) but it was observed in both normal and abnormal limbs in the study on horses with flexor tendon injury. It was regarded as an equivocal finding and, therefore, was not used as a separator variable when the sensitivity and specificity of the various combinations of separator variables were calculated.

A separator variable of any diagnostic test is a measurable property of the test which can be assessed, while a positivity criterion is the value of the separator variable that is taken as the dividing point between the diseased and normal populations (Weinstein and Fineberg, 1980). The ideal way to determine the positivity criterion is to use a method in which the cutoff points can be responsive to the consequences of different test results and that allows the prevalence of disease within a given population to be considered. In this way, as the prevalence of disease decreases, the cutoff point or positivity criterion should shift in the direction of greater stringency (Weinstein and Fineberg, 1980). However, in this study, neither of these factors were considered and the value of each parameter or separator variable at a variety of positivity criteria was assessed by examination of the sensitivity and specificity of the test using that variable. A receiver operator curve is a method by which the effectiveness of diagnostic tests can be compared and is constructed by plotting the true positive rate against the false positive rate (Weinstein and Fineberg, 1980). This method was used to compare the effectiveness of analysis of the maximum temperature difference with the difference in mean temperature of the thermograph and it indicated that both parameters were inefficient (Fig. 6.11).

A sensitive test is good at detecting patients with the disease and a specific test is good at screening out individuals which do not have the disease (Weinstein and Fineberg, 1980). While the ideal test is both sensitive and specific, in general terms, improvement of the sensitivity by the reduction of the stringency will result in poorer specificity (Weinstein and Fineberg, 1980). This effect was observed in this study when a variety of combinations of values of the differences in the mean temperature of the limbs and the maximum bilateral temperature differences were considered (Tables 6.6 and 6.7, Figs. 6.12 and 6.13). Again, the use of maximum temperature difference and the difference between the mean temperature differences, alone, or in combination, did not prove to be useful separator variables at the range of positivity criteria investigated (Tables 6.5, 6.6 and 6.7, Figs. 6.11, 6.12 and 6.13).

The other approach was to use the data collected in normal horses to calculate the mean and standard deviation of both the maximum temperature difference contralateral sites between the limbs and of the difference in mean temperature of the thermograph. Two standard deviations above and below the mean were taken as the normal range. This method of determining the cut-off point or positivity criterion can be criticised because it does not consider the rarity or frequency of the disease and the distribution of test results of the patients who have the disease and ignores the impact of false positive or false negative errors (Weinstein and Fineberg, 1980). A further criticism is that the normal horses in this study did not display a normal distribution around the mean (Figs. 6.1 and 6.2). However, as is illustrated in Fig. 6.8, (Population 1), while there is considerable overlap, a large proportion of group 6.3 fell outwith the normal range while the majority of group 6.10 and the normal horses were within the defined range for maximum and mean temperature differences. Nevertheless, the use of these two criteria without any other was neither sensitive or specific (Table 6.8, Population 1). The large number of bilateral injuries in the group contributed to this difficulty as this situation resulted in small differences in absolute temperature between limbs in most of the cases with bilateral injury.

A number of horses demonstrated decreased temperature below the normal range in the contralateral unaffected limb and this finding is difficult to explain (Table 6.4). Following the onset of injury, the animal's movement is likely to be restricted, usually as part of the therapeutic regimen. It may be that, in some way, this influenced the blood flow in the normal limb. Exercise results in an increase in skin surface temperature when measured shortly after completion (Turner, 1981). However, more detailed studies of the effect of restriction of exercise on local blood flow would be required to establish if restriction of exercise has any impact on the temperature of the limb. Nevertheless, the introduction of this feature as a separator variable did result in an improvement in the sensitivity of microwave thermographic examination in acute superficial digital flexor tendon injury (Table 6.8, population 1). Group 6.1 also had lower mean temperatures than Group 6.2 (Table 6.1) which included horses which were in full work and it may be that this influences the thermographic findings.

The use of all the parameters in combination was the most successful (Table 6.8, Population 1). In some cases, the absence of an abnormal temperature profile was compensated for by the presence of an abnormality in one or more of the other parameters. However, the best results which were obtained were a sensitivity of 80% and a specificity of 86%. An experienced clinician could be expected to achieve better results than this as there are few horses with acute flexor tendon injury in which one cannot be confident of the diagnosis on the basis of visual inspection and palpation.

Eight horses were examined on several occasions, a few days apart during the first four weeks of injury. While the results of thermographic examination were consistently abnormal, the precise recordings varied from examination to examination (Appendix 6.3). The repeatability of the technique could be criticised on this basis although repeatability studies for this machine on thermal models have been satisfactory (Land, 1987a). The other explanation is that the absolute temperature and temperature distribution in these limbs was indeed extremely variable. Unfortunately, this indicates that the technique could not be related directly to the severity of the lesion since the same lesion could produce a variety of results.

The results of these investigations on the use of microwave thermography as a diagnostic aid in acute injuries to the superficial digital flexor tendon were disappointing. The diagnostic capability of microwave thermography could be improved by the use of a number of parameters to assess the thermographs. However, the technique was not sufficiently accurate to enhance clinical examination and the results did not appear to offer the clinician an efficient and objective means of assessment of severity.

Chronic tendon injury has produced normal infrared thermographic recordings and both hot and cold spots have been observed (Stromberg, 1971; Webbon, 1978a). Abnormalities in temperature profile were recorded in some individuals in each group and at each duration included in this study. As is to be expected, the incidence of these abnormalities decreased with the duration of the lesion (Table 6.3). Similarly, the number of horses displaying a mean temperature below the normal range decreased with the duration of the lesion.

In a study of infrared thermographic features of chronic superficial digital flexor tendon injury, Stromberg (1971, 1973) described a maximum temperature difference of $1^{o}C$ below that of the contralateral, normal limb as a cold spot. However, the studies on microwave thermographic findings in normal horses demonstrated that greater differences in the deep body temperature are to be expected and, therefore, this finding was not considered as an abnormal feature in the horses with chronic tendon injury investigated in this study.

The sensitivity of the technique, using the selector variables which were defined using data from groups 6.1, 6.3 and 6.10, (Population 1), decreased with the age of the lesion while the specificity remained similar (Table 6.8). Temperature elevation is a feature of inflammation and, therefore, it is logical that as the early inflammatory reaction subsides, the thermographic evaluation should prove less useful. As a result, the technique is unlikely to be useful in the monitoring of healing.

It is important that tendon injury should be detected early to prevent more severe injury occurring as a consequence of continued athletic work (Stromberg, 1971). Infrared thermography has been proposed as a method for the early diagnosis of equine superficial digital flexor tendon injury and it has been shown to be successful as an objective means of demonstration of early lesions in Standardbred racehorses (Stromberg, 1971). In a proportion of the horses included in that study, the finding of infrared thermographic evidence of tendon injury was coincident with the onset of clinical signs although, in most of these cases, the clinical signs were mild. Obviously, the ability to appreciate the more subtle signs of tendon injury is variable and many experienced horsemen would be able to recognise the signs of slight swelling and pain on palpation which were documented in association with the appearance of thermographic evidence of tendon injury in this group. However, the most exciting finding in that study was that thermographic abnormalities were noted prior to the onset of clinical signs in six tendons in three horses.

In 12 tendons in ten horses, the only clinical sign which was present when thermographic abnormalities were noted was pain on palpation of the tendon which is a very subjective criterion. In this second group, continued work produced more overt signs of tendon injury on subsequent examinations.

A similar study was attempted in Thoroughbred horses trained for flat racing (Webbon, 1978a). Two horses had chronic tendon injuries but these did not recur and the thermographic findings in these individuals were consistently normal. A third horse had consistently abnormal thermographic findings but did not show signs associated with tendon injury although it was lame and a diagnosis of fetlock arthritis was reached. This may account for the abnormalities observed. However, in that study, no evidence was produced to support the theory that regular thermographic examination could be useful in the prevention of tendon injury. In part, this was because the group remained free from tendon injuries throughout the study period. Flexor tendon injury is more common amongst horses training for National Hunt racing (Evans, 1988) and, therefore, it was considered appropriate to attempt such a thermographic study in a group of these horses.

The horses were deliberately not examined by a Veterinary Surgeon unless the trainer requested and, therefore, the freedom from signs was his assessment and the description of these tendon injuries as subclinical relies on the opinion of the trainer. Nevertheless, none of these horses showed overt signs of tendon injury while the thermographic examination was performed but a full clinical evaluation was not made. The thermographs were reviewed retrospectively in an attempt to ensure that information obtained from them did not bias the opinion of the trainer.

Two horses sustained superficial digital flexor tendon injury during the study period (Cases 6.14 and 6.34; Figs. 6.18 and 6.19). In both these horses, the thermographs recorded approximately two weeks and one week prior to the onset of signs were considered to be abnormal in the affected limbs using the combination of criteria developed for the assessment of thermographs in acute tendon injury (Part 6.2). There was one horse (Case 6.27) which had chronic tendinitis and it repeatedly, but not consistently, displayed microwave thermographic abnormalities. In contrast, only one of three horses with chronic tendinitis demonstrated infrared thermographic abnormalities in a previous study (Webbon, 1978a).

A large number of horses which did not subsequently sustain flexor tendon injury also had positive thermographic signs and this resulted in low specificity (Table 6.9). However, sensitivity is the most desirable quality in a screening technique and the ability to identify individuals which might have the disease for further investigation is more important than eliminating the existence of the disease (Weinstein and Fineberg, 1980).

Profiles C and D were associated with superficial digital flexor tendon injury and profile F was not identified in the normal groups in section 6.1 but was occasionally observed in the normal contralateral limbs in horses with superficial digital flexor tendon injury in section 6.2. Profile F was not used as a diagnostic criterion previously but it was included as one of the variables in this part of the study because it describes localised, small increases of temperature which might be anticipated in early flexor tendon injury. However, its exclusion as a positive finding would have improved the specificity without influencing the sensitivity in this study as it was the only positive sign in five horses and 13 thermographs that were classified as abnormal (Table 6.9).

The use of the temperature profile as the only selector variable failed in the first abnormal thermograph in horse 6.34 which had normal temperature profiles but displayed a large difference in the mean temperatures of the limbs and in the maximum temperature difference between symmetrical points (Fig. 6.19). The use of a number of parameters in combination is likely to be more efficient although in this study the overall sensitivity is unchanged because the horse demonstrated abnormal profiles the following week. This is consistent with the findings of the studies on the use of microwave thermography in the assessment of acute and chronic tendon injury (Part 6.2) but in contrast to those studies greater flexibility in the number of diagnostic criteria did reduce the specificity markedly.

In view of the fact that only two animals sustained tendon injury, it is premature to state that this is a sensitive technique but these results do demonstrate potential in this regard. Further evaluation is required to prove the true effectiveness of microwave thermographic screening but the procedure is non--invasive, it is rapidly and easily performed and requires very little expertise; attributes which are also required for effective screening tools. The development of a computer package to perform the simple mathematical procedures required to assess the thermographs would greatly enhance its accessibility. These results are encouraging and are considered to justify further investigation.

CHAPTER 7.

GENERAL DISCUSSION:

NON-INVASIVE TECHNIQUES FOR THE INVESTIGATION OF SOFT TISSUE INJURY IN THE EQUINE LIMB: DIAGNOSTIC ULTRASONOGRAPHY AND MICROWAVE THERMOGRAPHY.

"It is my personal opinion that the musculoskeletal subspeciality, the "final frontier" is indeed the best. The case material, the variety of work, the challenges, and most of all, the camaraderie of the people involved are unrivalled in all diagnostic radiology. Although a long time in coming, the most exciting subspeciality in radiology has finally emerged from hiding and declared itself." (Sartoris, 1987).

In the above quotation from the American Journal of Roentgenology, Dr. Sartoris expresses enthusiasm for the potential of the recently developed imaging technologies which are available for use in the diagnosis of musculoskeletal disease. In the last two decades, interest in imaging methods which do not utilize ionising radiation has been stimulated by the recognition of the dangers to personnel and the environment that radiation poses. Currently, non-invasive methods are being developed and employed in all branches of medical sciences. Both diagnostic ultrasonography and microwave thermography are non-invasive: ultrasonography is based on sound waves of extremely low power which are believed to have no adverse biological effects (A.I.U.M., 1975); microwave thermography is a passive process and it records electromagnetic emission in the microwave part of the spectrum which are produced by the mamalian body (Land, 1987a; Land, 1987b). Medical ultrasonography was conceived in the early half of this century, but it was not developed to a practical and accessible form until the 1970's. It is now commonplace in all medical disciplines, including veterinary medicine, where imaging of soft tissue morphology is of value. Microwave thermography is a more recent innovation, and its use is currently investigative with applications in the diagnosis of mammary neoplasia, acute appendicitis and joint disease (Barrett and others, 1980; Myers, and others, 1980; Fraser and others, 1987; Stallard and others, 1987).

The purpose of this study was to assess the use of diagnostic ultrasonography and microwave thermography for the investigation of soft tissue injury of the equine limb and it was designed with consideration to the following general principles. A new diagnostic modality must be supported by adequate knowledge of its qualities and limitations if it is to be applied successfully in clinical practice. Normal findings and variations must first be established and aberration from normal defined. The accuracy of new techniques must be compared with other accepted standards and, if possible, comparative pathological examinations used to provide an indisputable control. The clinical application of new diagnostic techniques can then follow and ideally, clinical studies should be sufficiently extensive, and involve large numbers of animals, to allow meaningful application of the available data to a wide patient population.

The most efficient method to study diagnostic ultrasonography and microwave thermography was to concentrate on one specific soft tissue lesion, allowing investigation of a large number of affected cases and providing sufficient quantities of pathological material. It was hoped that these studies would also contribute to the understanding of that lesion. Injury of the equine superficial digital flexor tendon was selected as the appropriate subject as diagnostic aids for investigation of this tendon are a relatively recent innovation despite the fact that the condition is common and can be catastrophic (Rooney and Genovese, 1981; Jeffcott and others, 1982; Rossdale and others, 1985; Evans, 1988). Almost every facet of superficial digital flexor tendon injury remains controversial, most notably its aetiology and treatment, despite the recognition and study of this lesion which has been discussed frequently in equine veterinary literature since the publication of the earliest texts (Blundeville, 1565; Bracken, 1737; Vegetus Renatus, 1748; Hunter, 1796; Ferguson, 1862; Walsh, 1875a; Walsh, 1875b).

The specific aims of the study were to describe the normal ultrasonographic anatomy of the digital flexor tendons; to evaluate the relationship between ultrasonographic and pathological features of superficial digital flexor tendon injury; to compare ultrasonographic imaging with contrast radiography of the superficial digital flexor tendon; to describe the ultrasonographic features associated with acute tendon injury in a group of horses which could be re-examined throughout the course of healing of these lesions thus relating the eventual outcome of these cases with the ultrasonographic appearance and documenting the ultrasonographic changes associated with healing and determining the expected time course of these changes; to define the normal microwave thermographic appearance of the palmar metacarpal region and to determine the value of microwave thermography in the investigation of flexor tendon injury.

The application of diagnostic ultrasonography for the investigation of the equine superficial digital flexor tendon is not innovative: this application of ultrasonographic imaging was first proposed by Rantanen in 1982 and, by the time of completion of this study, it had been widely adopted by equine practitioners. The normal ultrasonographic appearance of the soft tissue structures of the palmar metacarpal region has been described (Hauser and others, 1982; Hauser and Rantanen, 1983; Modransky and others, 1983; Rantanen and others, 1983; Hauser and others, 1984; Spaulding, 1984; Genovese and others, 1986; Hauser, 1986). Nevertheless, quantitative data are lacking and the ultrasonographic anatomical studies described in Chapter 2 represent a quantitative investigation which has not been performed in this way previously. Unsuccessful attempts were made to obtain a normal relationship between the superficial digital flexor tendon and other anatomical landmarks, and to relate the size of the tendons to the weight and height of the individual horse. However, the range in normal size was narrow and the comparison of ultrasonographic measurement and gross pathological dimensions of normal flexor tendons, documented in Chapter 4, indicated that there was a close correlation between the two parameters and confirmed that the ultrasonographic measurements are representative of the actual dimensions of the tendons.

Thermographic techniques for the investigation of superficial digital flexor tendon injury have also been reported previously, but these procedures have not been widely embraced in the field (Stromberg, 1971; Stromberg, 1973). However, microwave thermography is a new technology which had not been utilized in veterinary medicine prior to this study. It has fundamental differences from infrared thermography, the more familiar form of temperature distribution mapping. These differences arise from the fact that microwave thermography is a measurement of deep body temperature, and they facilitate its use in an uncontrolled environment (Land, 1987a; Land, 1987b; Land and Brown, 1987). The description of normal findings and examination technique (Studies 6.1.1. and 6.1.2.), precedes the investigation of the clinical application of microwave thermography in equine superficial digital flexor tendon injury in Chapter 6.

The ultrasonographic findings in superficial digital flexor tendon injury in the horse have been reviewed by a number of authors (Spaulding, 1984; Genovese and others, 1985; Rantanen and others, 1985; Genovese and others, 1986; Genovese and others, 1987; Reef and others, 1988). The ultrasonographic findings in a number cases of superficial digital flexor tendon injury were described in Chapters 3 and 4, while abnormal microwave thermographic findings were defined in Chapter 6, Study 6.2. A grading system to describe the ultrasonographic appearance of tendon lesions has been proposed (Genovese and others, 1985). However, that method was not adopted in this study because it lacked detail, and the clinical material in Chapter 3 was used to develop a more complex, but more comprehensive, system for the description of the ultrasonographic findings. Any attempt to quantify subjective parameters must be performed with caution but this approach allowed the existence of trends to be demonstrated in the longitudinal study described in Chapter 5.

Chapter 3 and 4 have the additional, and the most important, aim of comparing the ultrasonographic findings with those of pathological and radiological investigations. Pathological comparison was the best method of confirmation of the validity of ultrasonographic examination as there is no other accepted standard for the diagnosis of superficial digital flexor tendon injury in life, and clinical examination is too subjective to be useful in this regard. The ultrasonographic findings did reflect the histological structure of the lesions and there was a consistent relationship between and the ultrasonographic, macroscopic and histological findings.

The relationship between the ultrasonographic appearance of superficial digital flexor tendon lesions and their histological composition had been reported previously as follows: lesions are anechoic while haemorrhage, oedema and early granulation tissue are present and the lesions become increasingly echogenic as collagen is deposited at the site of healing (Henry and others, 1986). In the study reported in Chapter 3, this relationship between the age and histological structure of the lesion and its ultrasonographic representation was confirmed, in general terms, but it was found to be more complex than that described by Henry and his co-workers (1986). Superficial digital flexor tendon lesions with haemorrhage, oedema, fibrolysis and early granulation tissue were represented ultrasonographically as either anechoic or hypoechoic areas which were well-defined from the surrounding tissue and lacked the normal linear echoes. The larger lesions tended to be anechoic while small lesions were more frequently, but not exclusively, hypoechoic. Zones of fibroplasia and granulation tissue were also hypoechoic and were well to moderately-defined with poorly-organised linear echoes. Henry and colleagues (1986) performed their study over a period of twenty-five weeks with surgically-created lesions. The current study included naturally occurring lesions of up to fourteen months' duration, allowing the ultrasonographic appearance of chronic fibrosis to be documented as heterogeneously echogenic on transverse images and composed disorganised linear echoes on longitudinal images, with intratendinous scar formation being represented by hyperechoic foci.

Contrast radiography is the earliest attempt to develop an imaging technique for the superficial digital flexor tendon, although it has not been adopted as a standard diagnostic method for tendon injury (Williams and Campbell, 1961). However, it has been advocated in this role, and contrast radiography was compared with ultrasonography in this study (Verschooten and De Moor, 1978; Verschooten and Picavet, 1986). Both techniques provided evidence of changes in dimension and shape of the superficial digital flexor tendon. Ultrasonographic examination was able to localise small lesions which were imperceptible by radiography and, as no assessment of intratendinous morphology was provided by air tendinography, the tendinograms did not add any further information to that available from ultrasonographic examination.

Air tendinography has been reputed to be an effective method for the demonstration of peritendinous inflammation, fibrosis and adhesion formation (Verschooten and De Moor, 1978; Verschooten and Picavet, 1986). In this study, both ultrasonography and air tendinography provided a limited, subjective assessment of the peritendinous tissue. Large areas of chronic granulation tissue lying between the skin and the palmar aspect of the superficial digital flexor tendon could be visualised and this was confirmed by post-mortem examination. However, adhesions between the superficial and deep digital flexor tendons were more difficult to characterise. Intertendinous adhesions are reported to result in poor clarity of the border between the superficial and deep digital flexor tendon on ultrasonographic images (Genovese and others, 1986; Genovese and others, 1987). However, this is an extremely subjective judgement. Poor separation between the flexor tendons is considered by previous authors to represent adhesion formation in air tendinograms (Verschooten and De Moor, 1978; Verschooten and Picavet, 1986). However, separation of the flexor tendons was not always achieved in normal limbs in this study and, thus, false positive tendinograms were obtained.

Ultrasonography was used as the "gold standard" to determine the sensitivity and specificity of microwave thermography. This mathematical method is ideal to determine the efficiency of a new diagnostic technique. It was not possible to use this means to evaluate ultrasonography itself as there was no existing "gold standard" with which to compare ultrasonography. However, in the pathological study in Chapter 3, ultrasonographic abnormalities were found in all the diseased limbs while no abnormalities were noted in the normal limbs in the anatomical studies, Chapter 2. Nevertheless, these studies were designed to determine the ultrasonographic findings in specific, known states and not to test the sensitivity and specificity of the technique.

Microwave thermography was not sensitive or specific in acute tendon injuries, and the results did not offer the clinician an efficient and objective means of assessment of severity. Equally, in chronic injuries, the true positive and negative rates were low and microwave thermography was not an objective guide to the status of healing of the injury.

The clinical application of diagnostic ultrasonography and microwave thermography in the investigation of superficial digital flexor tendon injury was the final line of investigation in this project. Chapters 2, 3 and 4 served as the necessary validation to support the clinical applications of diagnostic ultrasonography described in Chapter 5. Study 6.3, which addresses the value of microwave thermography as a screening technique for the detection of subclinical superficial digital flexor tendon injury, represents the development of a clinical application arising from the earlier studies in Chapter 6 and the technique showed potential as a screening tool for subclinical injury.

Numerous authors have stated that repeated ultrasonographic examinations to determine the progression of healing are invaluable in aiding the clinical management of horses with superficial digital flexor tendon injury (Rantanen and others, 1983; Pharr and Nyland, 1984; Genovese and others, 1985; Rantanen and others, 1985; Genovese and others, 1986; Hauser, 1986; Genovese and others, 1987; Reef and others, 1988). However, the study described in Chapter 5 is unique in that it documents the changes observed in a group of horses with superficial digital flexor tendon injury examined on multiple occasions.

The echogenicity, the linear echo arrangement and the distinctness of the lesion borders changed as the lesion healed, thus these parameters were useful criteria by which to assess healing of the lesion in an individual. Several distinct patterns of progression of echogenicity were identified and these could be related to the initial appearance and the severity of the lesion. Small, hypoechoic lesions healed most rapidly and these generally remained homogeneous as their echogenicity increased during the healing process. Anechoic lesions progressed to either uniform hypoechoic areas and ultimately echogenic areas or, in some cases during the healing phase, there was a heterogeneous appearance with mixtures of anechoic and hypoechoic areas. The most severe lesions tended to have extremely complex ultrasonographic findings and were comprised of multiple areas of varying echogenicity. The definition of the lesion border decreased and the presence and regularity of arrangement of the linear echoes increased with the duration of the lesions. Ultrasonography was effective in assessing subcutaneous haemorrhage and fibrosis but, as the comparative pathological and radiographic studies had indicated, in this study, difficulty was experienced in the determination of the presence of adhesions between the superficial and deep digital flexor tendons.

The bulk of the available details in the literature of the outcome of equine superficial digital flexor tendon injury is derived from studies of Standardbred racehorses and Thoroughbred horses engaged in flat racing. Only three studies have been performed in Britain which considered the outcome of tendon injury in National Hunt horses and these three reports aimed principally at describing treatment methods (Webbon, 1979; Goodship and others, 1980; Vaughan and others, 1985). It is surprising that there are not more reported data due to the high incidence of this injury amongst these horses. The collection of this information was a major aim of Chapter 5. Ultrasonographic examination allowed the subdivision of the group of horses based on the severity of their lesions. The influence of this and other factors such as age, sex, the presence of previous tendon injury and the treatment regimen on the proportion of each group returning to work, the retiral rate, the rate of recurrence of the injury and the duration of the lay-off period were examined.

Ultrasonography was a useful means of determining the severity of injury in the acute stages of superficial digital flexor tendon injury. In turn, severity was found to influence the outcome of the case significantly whereas the age, previous history and treatment regimen were not useful prognostic indicators. 42% of the cases in which the outcome was known at the end of the study returned to work with 27% racing again. The division of the population into groups of mild, moderate and severe lesions based on the ultrasonographic examination demonstrated that there were marked differences in outcome: only 7% of severe cases raced again although 30% were returned to work; 22% of moderate cases raced and 38% returned to work while 62% of mild cases raced and 100% returned to work.

A previous study which had been conducted in Thoroughbreds racing on the flat and Standardbred racehorses in the U.S.A., reported that no individuals with anechoic lesions which comprised 25% or greater of the cross-sectional area of the tendon recovered successfully (Genovese and others, 1987). Clearly, the prognosis for National Hunt racehorses sustaining superficial digital flexor tendon injury is much better as all the horses classified as moderate and severe, and some of the horses classified as having mild lesion, would have been included in Genovese's description. The reasons for the more favourable outcome presumably arise from differences in management practices including the fact that extended periods of rest are possible, although not desirable, in National Hunt racehorses due to their longer working life.

Further subdivision of the group of horses on the basis of the ultrasonographic findings would have been possible: for example, attempts to establish a relationship between the length or cross-sectional area of the lesion and the clinical outcome could have been undertaken. However, conventional statistical methods assume that, if a relationship exists, it is linear. Obviously, in nature, this is not necessarily the case. Advanced, artificial intelligence methods are currently being developed to demonstrate non-linear relationships. The number of animals with known outcome included in the current study did not justify this approach at present. However, these individuals may be included in such a study in future.

Ultrasonographic examination has been hailed as a new way in which clinical trials on the treatment of tendon injuries can be performed objectively (Genovese and others, 1987). The degree of objectivity remains operator dependent, but it allows measurements to be made and permanent records of the appearance of lesions to be obtained. Microwave thermography is not sufficiently accurate and there is too much variation within individuals from day to day to be a useful monitoring technique.

The treatment of tendon injuries was addressed in a limited way in this study, but the majority of the information collected on clinical outcome relates to the conservative management. The study group was subdivided on the basis of the treatment regimen: conservative management, laser therapy or glycosaminoglycan administration. Unfortunately, the latter two groups were small and the groups were not matched according to the severity of the lesions. No significant difference in outcome was observed between the three treatment groups nevertheless, the final outcome of the cases treated conservatively compared favourably with both of the other treatment groups and the data reported previously from horses treated with carbon fibre implants (Goodship and others, 1980; Vaughan and others, 1985).

The selection of an end-point for studies on the outcome of tendon injuries is a controversial issue and, in the veterinary literature, numerous methods have been adopted. Ideally, the cases should be followed for several years because of the long clinical course of the lesion. However, in this study that was not possible and, therefore, several parameters were used to assess the outcome of the individual cases. Analysis of these cases in future may demonstrate more of these individuals will ultimately race again and also a higher recurrence rate.

The pathogenesis of superficial digital flexor tendon injuries was not addressed in this study. It is likely that clinical tendon injury is preceded by a phase in which there is first damage at the molecular and the microscopic and subclinical levels (Diamant and others, 1972; Mosler and others, 1985; Knorzer and others, 1986; Stromberg, 1971). A degenerative process, due to inadequate blood supply, has been speculated (Stromberg and Tufvesson, 1969; Stromberg, 1971; Stromberg, 1873). But, the lesion may be the result simply of repeated traumatic events (Diamant and others, 1972; Mosler and others, 1985; Knorzer and others, 1986).

Some authors have stated that ultrasonography is capable of demonstrating tendon lesions in the absence of clinical signs (Rantanen and others, 1985; Genovese and others, 1987). The current study did not investigate this issue as the animals which underwent ultrasonographic examination had been referred for the investigation of the superficial digital flexor tendon following the detection of localising signs. However, both limbs were examined in all cases regardless of whether the owner or referring veterinarians suspected a bilateral injury. Frequently, lesions were demonstrated which had not been suspected by the owner but, in all of these cases, mild swelling and sometimes, palpable heat was detected in the area of the superficial digital flexor tendon. Obviously, the definition of subclinical depends on the examiner.

Microwave thermographic abnormalities were detected in horses prior to the appearance of clinical signs. However, there was also a high incidence of microwave thermographic abnormalities in horses which did not subsequently demonstrate tendon lesions. It may be that all of those individuals had microscopic lesions but that cannot be stated with certainty. It is unlikely that microwave thermography, used in isolation, will be able to determine the true incidence of subclinical tendon injury. However, the two techniques were used in combination may meet that objective in a future study. More widespread use of these technologies may limit the severity of tendon lesions and, thus by their early detection, improve the clinical outcome. Nevertheless, surveys utilizing either technique are unlikely to resolve the question if degenerative processes complicate a purely mechanical aetiology.

Recurrence of the tendon injury following the return to work is a well-documented problem: in the current study the overall recurrence rate was 35%. Histologically, the "healed" tendon lacks the organised arrangement of the normal tendon and the endotenon tends to be hypercellular. Extremely ill-defined lesions are apparent on ultrasonographic examination of these cases, in which the most striking feature is a slight degree of disorganisation of the linear echoes which comprise the longitudinal image of the tendon. In such areas, where the longitudinal arrangement of the collagen bundles is disrupted, the functional integrity of the tendon is reduced. These ultrasonographic studies demonstrated that tendon re-injuries were generally more severe, with a history of previous tendon injury having a highly significant effect on the severity of the lesions. Mild, first-time lesions were most commonly located in the central third of the tendon and moderate, repeated lesions involved the distal and middle thirds of the tendon. In the most severe lesions, including some of those incorporated in the pathological studies, the entire length of the tendon was involved but the most extensive damage was located in the distal third. Re-injury is thought to occur at the site at which the injured tendon joins the previously undamaged area (Bramlage, 1983). This distribution supports this theory but, in all cases, the lesion also extended proximally into the site of previous damage.

The additional role of peritendinous adhesion in inhibiting the gliding action of the tendon and leading to the recurrence of the lesion is postulated, and some modes of therapy are aimed at reducing or removing such adhesions (Selway, 1975). Ultrasonography is a subjective means of assessing adhesion formation and it is unlikely that ultrasonographic studies will be able to contribute to study of the significance of adhesion formation.

These studies were conducted entirely on horses with naturally occurring tendon lesions, thus, they constitute clinical rather than experimental research. Experimental studies have the advantage that a carefully controlled set of criteria and conditions can be applied to the study population. Clinical investigations tend to be limited by the diversity of the material and are more observational. However, the use of live animals for experimental purposes is of increasing ethical concern, and it is essential that this should be avoided wherever possible. The development and promotion of non-invasive methods for the investigation of soft tissue injury is the concept which underlies the current investigation. The use of naturally occurring cases allowed a large number of horses to be included in the studies and data were obtained on a scale which would be extremely difficult to justify in an experimental study.

A clinical study lacks the standardization which is possible in a well-designed experimental investigation. A simple approach to the classification of the severity of the lesions and the clinical end-points was required due to the diversity within the group and to avoid the over interpretation of the data. Ultimately, ultrasonographic examination depends on the ability of the operator and their interpretation of the findings.

Initially, it was hoped that the quantitative nature of microwave thermographic examination would enhance the objectivity of the study. Unfortunately, this was not the case as there was no apparent relationship between the microwave thermographic findings and the severity of the lesion and the technique became progressively less efficient with the duration of the lesion.

In summary, these studies are considered to have met the objectives which were defined in the introduction, Chapter 1. The ultrasonographic and microwave thermographic findings associated with the superficial digital flexor tendon in the normal and abnormal state have been described while clinical applications of both techniques have been explored.

This study has provided a better understanding of the relationship between the ultrasonographic and pathological findings, documented the ultrasonographic progression of healing and showed that these changes can be related to the morphology of the tendon lesion. Ultrasonography is an effective means of demonstration of the severity of tendon lesion and the final outcome of an individual case can be related to this. Its use as a tool for monitoring healing has been documented in detail and the progression of changes has been described.

Microwave thermography is limited in its efficiency as a diagnostic aid in clinical cases, but abnormalities were demonstrated prior to clinical signs, and it is in this area that the technique is believed to have most potential.

The data relating to the clinical outcome of the horses included in this study may be of use to equine practitioners in providing the basis for a prognosis for individual cases and they refer specifically to a group of horses in which precise details of the eventual outcome has not been documented in detail, namely horses competing in National Hunt and Point-to-point racing.

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APPENDIX 2.1. THE AGE, SEX, HEIGHT, WEIGHT AND NORMAL DIMENSIONS OF FLEXOR TENDONS AT VARIOUS LOCATIONS RECORDED IN 25 NORMAL HORSES.

CASE NO.	AGE (years)	SEX	HEIGHT (h.h.)	WEIGHT (kgs)
2.1	12	F	16.1	530
2.2	6	M/N	16.2	540
2.3	15	M/N	16.1	490
2.4	10	F	16.2	570
2.5	5	M/N	16.3	520
2.6	10	F	15.3	450
2.7	14	F	16.1	490
2.8	20	M/N	16.3	580
2.9	5	F	16	530
2.10	7	M/N	16.2	580
2.11	20	M/N	15.3	500
2.12	15	M/N	16	500
2.13	7	F	15.3	520
2.14	8	F	16	490
2.15	6	F	16.3	560
2.16	7	M/N	17	500
2.17	20	F	16.1	560
2.18	8	F	15.1	540
2.19	20	F	16.2	470
2.20	20	M/N	16	480
2.21	14	F	15.1	460
2.22	3	M/N	16.1	490
2.23	15	F	15.3	410
2.24	15	M/N	16	520
2.25	4	M/N	15.3	490
MEAN	11.44		16	510
S.D.	5.72			42

CASE NO.	6SDP	6DDP	6SLM	6DLM	6CIRC	6MCD
2.1	5.00	7.50	13.50			
	5.00	9.00	16.50	13.50		
2.2	6.50	10.00				
	5.00	10.00	10.50	9.00		
2.3	7.50	11.50	15.00	12.00	230.00	65.00
	7.00	8.00	18.00	11.50	240.00	72.00
2.4	6.50	8.00	17.00	13.50	245.00	74.00
2.5	5.00	8.00	18.00	16.50	250.00	74.00
	5.50	10.00	18.00	15.00	225.00	86.00
2.6						
2.7					240.00	72.00
2.8	8.00	9.00	15.00	12.00	255.00	74.00
	6.50	8.50	12.00	13.50	260.00	75.00

2.9	5.00	6.50	15.00	12.00		
	7.50	11.50	15.00	13.50		
2.10					232.00	60.00
					240.00	62.00
2.11	6.00	8.50	15.00	13.50	215.00	53.00
	8.50	6.50	10.50	13.50	220.00	68.00
2.12						
	7.00	8.50	13.50	15.00		
2.13	7.50	8.50			245.00	73.00
2.14						
2.15					205.00	58.00
	6.00	10.00	15.00	13.50		57.00
2.16	5.00	10.00	16.50	13.50		
2.17						
2.18	5.00	7.00	18.00	16.00	210.00	57.00
	6.00	10.00	16.50	12.00	215.00	56.00
2.19					255.00	
					255.00	
2.20	5.00	10.00	10.50	9.00	220.00	66.00
	6.50	10.00			230.00	68.00
2.21					215.00	79.00
					230.00	71.00
2.22	5.00	9.00	16.50	13.50		
	5.00	7.50	13.50	10.50		
2.23	7.00	8.00	18.00	11.50	215.00	
	7.50	11.50	15.00	12.00	210.00	
2.24	6.50	8.00	17.00	13.50	265.00	82.00
					280.00	84.00
2.25	5.50	10.00	18.00	15.00		
	5.00	8.00	18.00	16.50		
MEAN	6.14	8.66	15.30	13.06	235.30	68.95
S.D.	1.10	1.30	2.40	2.17	19.00	9.34

CASE NO.	**8SD**	**8DDP**	**8SLM**	**8DLM**	**8CIRC**	**8MCD**
2.1	5.00	8.00	15.00	13.50	230.00	60.00
	5.00	10.00	12.00	10.50	230.00	52.00
2.2	6.50	10.00				
	4.00	9.00	12.00	13.50	220.00	56.00
2.3					220.00	57.00
	6.00	10.00	15.00	11.00	220.00	58.00
2.4	6.50	8.00	15.00	12.00	225.00	68.00
	5.00	10.00	18.00	15.50	240.00	78.00
2.5	6.50	8.00	16.50	15.00	235.00	60.00
	5.50	8.00	18.00	15.20	235.00	68.00
2.6	7.00	8.00	15.00	11.00	220.00	72.00
	9.00	6.00	14.00	13.00	200.00	55.00
2.7	8.00	8.00	16.00	13.00	230.00	56.00
	8.00	8.00	16.00	12.00	250.00	60.00
2.8	8.00	11.50	13.50	10.50	230.00	64.00

	6.50	6.50	15.00	12.00	232.00	68.00
2.9	5.00	6.50	15.00	12.00	230.00	54.00
	5.00	6.50	18.00	12.00	230.00	55.00
2.10	8.50	8.50	21.00	12.00	220.00	52.00
	5.00	6.50	15.00	12.00	225.00	60.00
2.11	5.00	6.50	18.00	15.00	210.00	44.00
	6.50	6.50	13.50	15.00	210.00	50.00
2.12					265.00	75.00
	6.50	8.50	13.50	10.50	240.00	70.00
2.13	6.50	8.50	18.00	13.50	220.00	60.00
	5.00	6.50	16.50	15.00	240.00	55.00
2.14	5.50	11.00	15.00	15.00	230.00	58.00
	6.50	10.00	15.00	13.50	235.00	59.00
2.15	5.00	11.00	16.50	13.50	200.00	52.00
	5.00	10.00	15.00	13.00	215.00	57.00
2.16	6.50	10.00	16.50	13.50	230.00	62.00
	5.00	10.00	13.50	12.00	230.00	53.00
2.17	6.50	8.50	16.50	15.00	250.00	77.00
	7.50	6.50			225.00	59.00
2.18	7.00	7.00	16.00	12.00	200.00	59.00
	6.00	9.50	15.00	10.50	200.00	48.00
2.19	7.00	8.00	15.00	11.00	223.00	68.00
	9.00	6.00	14.00	13.00	215.00	58.00
2.20	4.00	9.00	12.00	13.50	205.00	52.00
	6.50	10.00			205.00	56.00
2.21	8.00	8.00	16.00	12.00	207.00	57.00
	8.00	8.00	16.00	13.00	213.00	58.00
2.22	5.00	10.00	12.00	10.50	220.00	72.00
	5.00	8.00	15.00	13.50	212.00	60.00
2.23	6.00	10.00	15.00	11.00	205.00	50.00
					205.00	50.00
2.24	6.50	8.00	15.00	12.00	218.00	67.00
	5.00	10.00	18.00	12.50	235.00	73.00
2.25	5.50	8.00	18.00	15.20	230.00	74.00
	6.50	8.00	16.50	15.00	225.00	60.00
MEAN	6.16	8.40	15.48	12.80	223.20	60.12
S.D.	1.28	1.47	1.91	1.60	14.07	8.06

CASE NO.	**10SDP**	**10DD**	**10SL**	**10DL**	**10CIR**	**10MC**
2.1	5.00	10.00	15.00	12.00	215.00	52.00
	5.00	8.00	15.00	12.00	210.00	52.00
2.2	6.50	11.50			225.00	58.00
	5.00	10.00	14.00	13.00	215.00	48.00
2.3	5.00	10.00	13.50	12.00	210.00	49.00
	6.00	10.00	15.00	11.00	210.00	51.00
2.4	6.00	6.50	16.50	12.00	215.00	68.00
	5.00	8.00	19.50	15.00	225.00	64.00
2.5	5.00	8.00	17.50	16.50	225.00	55.00
	6.00	8.00	19.50	18.00	228.00	57.00
2.6	7.00	8.00	17.00	13.00	200.00	52.00
	6.00	9.00	13.00	13.00	195.00	49.00
2.7	7.00	9.00	17.00	13.00	215.00	53.00
	9.00	7.00	15.00	12.00	230.00	57.00

2.8	6.50	8.50	16.50	12.00	225.00	58.00
	6.50	6.00	13.50	10.50	222.00	60.00
2.9	6.50	6.50	12.00	10.50	210.00	50.00
	5.50	8.50	18.00	12.50	215.00	48.00
2.10	6.00	6.50	16.50	13.50	210.00	48.00
	5.50	6.50	18.00	12.00	210.00	57.00
2.11	5.50	8.50	16.50	15.00	205.00	42.00
	5.50	10.00	15.00	13.50	200.00	44.00
2.12	6.50	10.00	12.00	10.50	230.00	55.00
	6.50	8.50	15.00	10.50	210.00	50.00
2.13	6.50	8.50	16.50	13.50	210.00	52.00
	5.50	8.50	13.50	12.00	220.00	50.00
2.14	6.50	10.00			215.00	45.00
	8.50	9.00	15.00	13.50	210.00	47.00
2.15	5.00	10.50	16.50	13.50	195.00	47.00
	5.00	11.00	16.50	13.50	205.00	54.00
2.16	5.00	10.00	16.50	13.00	220.00	57.00
	5.50	10.00	15.00	13.50	210.00	52.00
2.17	5.00	8.50	18.00	16.00	220.00	57.00
	7.50	7.50	15.00	12.00	210.00	53.00
2.18	7.00	8.00	20.00	15.00	195.00	45.00
	5.50	10.00	15.00	8.50	195.00	44.00
2.19	7.00	8.00	17.00	13.00	202.00	57.00
	6.00	9.00	13.00	13.00	200.00	51.00
2.20	5.00	10.00	13.50	12.00	200.00	46.00
	5.00	10.00	14.00	13.00	200.00	48.00
2.21	9.00	7.00	15.00	12.00	205.00	52.00
	7.00	9.00	17.00	13.00	205.00	50.00
2.22	5.00	8.00	15.00	12.00	215.00	60.00
	5.00	10.00	15.00	12.00	215.00	55.00
2.23	6.00	10.00	15.00	11.00	203.00	47.00
	5.00	10.00	13.50	12.00	200.00	47.00
2.24	6.00	6.50	16.50	12.00	208.00	55.00
	5.00	8.00	19.50	15.00	218.00	60.00
2.25	6.00	8.00	19.50	18.00	210.00	55.00
	5.00	8.00	17.50	16.50	208.00	53.00
MEAN	5.90	8.76	15.50	12.80	210.98	52.20
S.D.	0.94	1.42	2.21	1.87	9.48	5.30

CASE NO.	**12SD**	**12DD**	**12SL**	**12DL**	**12CIR**	**12MC**
2.1	6.00	9.00	16.50	13.50	200.00	48.00
	5.00	8.50	15.00	10.50	205.00	52.00
2.2	7.00	8.50	13.50	10.50	215.00	54.00
	5.00	10.00	17.00	13.50	210.00	46.00
2.3	5.00	6.50	18.00	13.50	210.00	48.00
	5.50	11.50	17.00	11.00	205.00	46.00
2.4	6.50	8.50	15.00	12.00	220.00	54.00
	5.00	8.50	18.00	13.50	215.00	56.00
2.5	5.50	10.00	18.00	16.50	220.00	50.00
	5.00	10.00	21.00	18.00	215.00	51.00
2.6	7.00	9.00	15.00	10.00	190.00	48.00
	8.00	7.00	16.00	12.00	185.00	44.00
2.7	8.00	9.00	16.00	13.00	210.00	48.00

	6.00	10.00	15.00	13.00	215.00	55.00
2.8	7.50	8.50	18.00	10.50	220.00	54.00
	6.00	7.50	16.50	10.50	218.00	55.00
2.9	5.00	6.50	15.00	10.50	206.00	49.00
	5.00	8.50	20.00	12.00	210.00	48.00
2.10	6.00	6.50	18.00	15.00	210.00	48.00
			18.00	13.50	210.00	50.00
2.11	5.00	7.50	15.00	13.50	205.00	47.00
	5.00	10.00	13.50	13.50	195.00	42.00
2.12	6.50	7.50	13.50	12.00	220.00	48.00
	6.50	6.50	13.50	9.00	210.00	46.00
2.13	6.50	8.50	15.00	12.00	210.00	45.00
	5.00	8.50	15.00	12.00	215.00	48.00
2.14	5.00	6.50	16.00	14.00	200.00	47.00
					200.00	48.00
2.15	5.00	8.50	17.00	13.50	195.00	45.00
	5.00	8.50	18.00	13.50	200.00	49.00
2.16	5.00	10.00	16.50	12.50	215.00	53.00
	5.00	10.00	13.50	10.50	210.00	53.00
2.17	5.00	9.50	16.50	13.50	210.00	50.00
	6.00	6.50	15.00	12.00	203.00	48.00
2.18	7.00	7.00	20.00	13.00	190.00	44.00
	5.00	7.50	18.00	12.50	190.00	42.00
2.19	7.00	9.00	15.00	10.00	198.00	49.00
	8.00	7.00	16.00	12.00	195.00	46.00
2.20	5.00	10.00	17.00	13.50	198.00	46.00
	7.00	8.50	13.50	10.50	195.00	45.00
2.21	6.00	10.00	15.00	13.00	200.00	46.00
	8.00	9.00	16.00	13.00	200.00	45.00
2.22	5.00	8.50	15.00	10.50	213.00	54.00
	6.00	9.00	16.50	13.50	212.00	51.00
2.23	5.50	11.50	17.00	11.00	210.00	48.00
	5.00	6.50	18.00	13.50	200.00	46.00
2.24	6.50	8.50	15.00	12.00	202.00	50.00
	5.00	8.50	18.00	13.50	210.00	53.00
2.25	5.00	10.00	18.00	16.50	210.00	53.00
	5.50	10.00	21.00	18.00	210.00	55.00
MEAN	5.75	8.40	16.30	12.60	206.20	48.90
S.D.	0.93	1.30	1.90	1.92	8.83	3.60

CASE NO.	**14SD**	**14DD**	**14SL**	**14DL**	**14CIR**	**14MC**
2.1	6.00	8.50	16.50	12.00	205.00	48.00
	5.00	8.50	16.50	10.50	200.00	45.00
2.2	6.00	10.00	15.00	12.00	215.00	48.00
	6.00	8.50	15.00	9.00	210.00	44.00
2.3	6.00	10.00	16.50	12.00	205.00	46.00
	4.50	8.00	18.00	10.50	205.00	45.00
2.4	5.00	7.00	15.00	11.50	215.00	50.00
	6.50	7.50	18.00	14.00	215.00	54.00
2.5	6.50	9.50	19.00	15.00	219.00	48.00
	5.00	8.50	21.00	18.00	214.00	49.00
2.6	6.00	6.00	16.00	11.00	190.00	44.00
	6.00	7.00	14.00	11.00	185.00	42.00

2.7	7.00	9.00	16.00	12.00	210.00	47.00
	7.00	10.00	16.00	11.00	210.00	50.00
2.8	7.50	8.50	18.00	10.50	215.00	49.00
	5.00	6.50	18.00	12.00	212.00	50.00
2.9	5.00	10.00	15.00	10.50	205.00	48.00
	5.00	6.50	21.00	15.00	210.00	48.00
2.10	5.00	8.50	15.00	12.00	210.00	46.00
	5.00	6.50	16.50	10.50	210.00	47.00
2.11	5.00	6.50	15.00	12.00	200.00	44.00
	5.00	6.50	13.50	13.50	200.00	42.00
2.12	5.00	8.50	16.50	12.00	220.00	46.00
	6.50	6.50	12.00	9.00	210.00	44.00
2.13	6.50	8.50	13.50	13.50	210.00	45.00
	5.00	8.50	13.50	12.00	218.00	48.00
2.14	6.00	7.50	15.00	12.00	205.00	48.00
	6.50	8.50	15.00	12.00	200.00	47.00
2.15	5.00	8.50	18.00	12.00	195.00	44.00
	5.00	10.00	15.00	11.00	195.00	45.00
2.16	4.00	10.00	16.50	13.50	210.00	48.00
	5.00	8.50	15.00	12.00	210.00	48.00
2.17	6.00	8.50	16.50	15.00	210.00	49.00
	6.50	8.00	17.50	14.00	202.00	45.00
2.18	5.00	8.00			190.00	43.00
	5.00	10.00	18.00	12.00	190.00	41.00
2.19	6.00	6.00	16.00	11.00	198.00	46.00
	6.00	7.00	14.00	11.00	194.00	44.00
2.20	6.00	8.50	15.00	9.00	195.00	45.00
	6.00	10.00	15.00	12.00	195.00	44.00
2.21	7.00	10.00	16.00	11.00	200.00	47.00
	7.00	9.00	16.00	12.00	198.00	45.00
2.22	5.00	8.50	16.50	10.50	212.00	49.00
	6.00	8.50	16.50	12.00	212.00	53.00
2.23	4.50	8.00	18.00	10.50	208.00	47.00
	6.00	10.00	16.50	12.00	195.00	45.00
2.24	5.00	7.00	15.00	11.50	200.00	47.00
	6.00	7.50	18.00	14.00	205.00	48.00
2.25	5.00	8.50	21.00	18.00	210.00	53.00
	6.50	9.50	19.00	15.00	208.00	50.00
MEAN	5.69	7.98	16.30	11.90	205.10	46.76
S.D.	0.98	1.97	1.92	2.10	8.43	2.78

CASE NO.	**16SD**	**16DD**	**16SL**	**16DL**	**16CIR**	**16MC**
2.1	4.00	8.50	16.50	13.50	205.00	48.00
	3.00	8.50	16.50	12.00	200.00	45.00
2.2	8.00	10.00	16.50	13.50	215.00	46.00
	6.00	11.50	15.00	10.50	210.00	44.00
2.3	6.00	10.00	18.00	13.50	210.00	46.00
	4.00	8.50	18.00	12.00	205.00	45.00
2.4	4.00	8.50	15.00	12.00	220.00	50.00
	6.00	8.50	21.00	15.00	215.00	52.00
2.5	5.00	9.00	20.00	13.50	218.00	48.00
	5.00	8.50	20.00	13.50	215.00	48.00
2.6	8.00	7.00	12.00	10.00	190.00	42.00

	5.00	9.00	17.00	13.00	185.00	41.00
2.7	6.00	7.00	17.00	12.00	210.00	47.00
	7.00	9.00	17.00	11.00	210.00	47.00
2.8	6.50	10.00	18.00	10.50	215.00	46.00
	4.00	8.50	16.50	13.50	212.00	47.00
2.9	5.00	8.50	18.00	12.00	210.00	49.00
	5.00	7.50	21.00	15.00	210.00	47.00
2.10	6.00	6.50	16.50	12.00	220.00	46.00
	5.00	6.50	16.50	10.50	210.00	47.00
2.11	5.00	6.50	15.00	10.50	200.00	45.00
	5.00	6.50	15.00	12.00	195.00	43.00
2.12	5.00	7.50	13.50	12.00	210.00	47.00
	6.50	6.50	12.00	9.00	210.00	45.00
2.13	6.00	9.00	16.50	12.00	210.00	45.00
	6.00	7.50	13.50	12.00	218.00	45.00
2.14	6.00	7.50	15.00	15.00	205.00	44.00
	6.00	9.00	18.00	13.50	200.00	45.00
2.15	4.50	11.00	18.00	15.00	200.00	44.00
	5.00	10.00	18.00	13.50	195.00	44.00
2.16	4.00	10.00	18.00	14.00	210.00	47.00
	3.50	8.50	18.00	14.00	210.00	46.00
2.17	3.50	9.00	18.00	15.00	207.00	46.00
	5.00	8.50	15.00	12.00	202.00	44.00
2.18	5.00	9.00	19.50	13.50	190.00	41.00
	5.00	7.50	19.50	14.00	190.00	41.00
2.19	8.00	7.00	12.00	10.00	194.00	44.00
	5.00	9.00	17.00	13.00	194.00	43.00
2.20	6.00	11.50	15.00	10.50	195.00	44.00
	8.00	10.00	16.50	13.50	195.00	44.00
2.21	7.00	9.00	17.00	11.00	200.00	44.00
	6.00	7.00	17.00	12.00	198.00	45.00
2.22	3.00	8.50	16.50	12.00	212.00	47.00
	4.00	8.50	16.50	13.50	212.00	48.00
2.23	4.00	8.50	18.00	12.00	210.00	45.00
	6.00	10.00	18.00	13.50	193.00	44.00
2.24	4.00	8.50	15.00	12.00	198.00	44.00
	6.00	8.50	21.00	15.00	202.00	47.00
2.25	5.00	8.50	20.00	13.50	205.00	45.00
	5.00	9.00	20.00	13.50	205.00	47.00
MEAN	5.34	8.56	16.96	12.61	204.90	45.50
S.D.	1.24	1.24	22.20	1.50	8.79	2.27

CASE NO.	**18SD**	**18DD**	**18SL**	**18DL**	**18CIR**	**18MC**
2.1	4.00	8.50	18.00	11.00	205.00	46.00
	3.50	8.50	15.00	12.00	205.00	45.00
2.2	6.50	10.00	16.50	12.00	220.00	46.00
	5.00	11.50	16.50	12.00	215.00	44.00
2.3	4.00	11.00	18.00	13.50	210.00	46.00
	6.00	8.00	18.00	12.00	210.00	46.00
2.4	4.00	11.50	18.00	13.50	230.00	48.00
	6.00	7.50	20.00	14.50	225.00	52.00
2.5	5.00	8.00	20.50	14.50	220.00	48.00
	5.00	8.00	22.50	15.00	216.00	47.00

2.6	6.00	7.00	16.00	10.00	190.00	42.00
	6.00	11.00	18.00	10.00	185.00	40.00
2.7	7.00	9.00	18.00	11.00	210.00	48.00
	5.00	8.00	18.00	12.00	210.00	46.00
2.8	6.50	11.50	18.00	15.00	217.00	45.00
	4.00	8.50	18.00	12.00	215.00	45.00
2.9	3.50	7.50	19.50	10.50	210.00	50.00
	5.00	11.50			208.00	47.00
2.10	5.00	8.50	19.50	13.50	215.00	49.00
	5.00	9.00	18.00	12.00	210.00	46.00
2.11	5.00	6.50	18.00	12.00	200.00	45.00
	4.00	8.50	16.50	12.00	200.00	40.00
2.12	4.00	8.50	15.00	12.00	215.00	47.00
	5.00	7.50	13.50	10.50	210.00	45.00
2.13	5.00	6.50	16.50	12.00	210.00	46.00
	6.50	8.50	13.50	10.50	210.00	45.00
2.14	5.00	10.00	15.50	13.50	205.00	45.00
	5.50	8.50	16.50	13.50	200.00	44.00
2.15					200.00	45.00
	4.50	11.50	18.00	11.00	200.00	44.00
2.16	5.00	8.50	19.50	11.50	210.00	46.00
	3.50	10.00	18.00	11.50	210.00	45.00
2.17	3.50	8.50	18.00	10.50	203.00	44.00
	4.50	8.50	19.50	12.00	205.00	45.00
2.18			20.00	11.00	190.00	42.00
	4.50	7.50	20.00	11.00	190.00	41.00
2.19	6.00	7.00	16.00	10.00	195.00	44.00
	6.00	11.00	18.00	10.00	195.00	44.00
2.20	5.00	11.50	16.50	12.00	198.00	45.00
	6.50	10.00	16.50	12.00	196.00	43.00
2.21	5.00	8.00	18.00	12.00	200.00	44.00
	7.00	9.00	18.00	11.00	200.00	46.00
2.22	3.50	8.50	15.00	12.00	215.00	47.00
	4.00	8.50	18.50	11.00	212.00	48.00
2.23	6.00	8.00	18.00	12.00	205.00	45.00
	4.00	11.00	18.00	13.50	195.00	45.00
2.24	4.00	11.50	18.00	13.50	200.00	43.00
	6.00	7.50	20.00	14.50	202.00	45.00
2.25	5.00	8.00	22.50	15.00	205.00	48.00
	5.00	8.00	20.50	14.50	200.00	49.00
MEAN	5.01	8.92	17.85	12.14	206.00	45.22
S.D.	0.99	1.49	1.92	1.45	9.23	2.72

CASE NO.	**20SD**	**20DD**	**20SL**	**20DL**	**20CIR**	**20MC**
2.1	3.50	11.50	18.50	13.50	205.00	45.00
	3.00	8.50	22.00	14.00	205.00	45.00
2.2	7.50	9.50	13.50	12.00	220.00	46.00
	6.00	11.50	18.00	13.50	215.00	45.00
2.3					220.00	50.00
	6.50	10.00	18.00	14.00	210.00	47.00
2.4	5.00	8.50	21.00	15.00	220.00	47.00
	3.50	10.00	22.50	16.50	225.00	53.00
2.5	6.50	11.50	20.00	15.00	222.00	49.00

	5.00	6.50	18.00	15.00	218.00	47.00
2.6	7.00	7.00	17.00	11.00	190.00	42.00
	7.00	11.00	17.00	11.00	190.00	41.00
2.7	5.00	10.00	17.00	11.00	215.00	50.00
	5.00	7.00			205.00	47.00
2.8	6.50	13.00	20.00	15.00	222.00	47.00
	5.00	11.50	19.50	15.00	220.00	46.00
2.9	4.00	11.50	18.00	13.50	210.00	49.00
	5.00	10.00			210.00	48.00
2.10	5.00	6.50	21.00	15.00	220.00	49.00
	5.00	9.00	18.00	13.50	210.00	46.00
2.11	3.00	7.50	21.00	15.00	205.00	43.00
	3.00	10.00	19.50	13.50	200.00	44.00
2.12	3.50	8.50	15.00	12.00	210.00	49.00
	5.00	7.50	15.00	10.50	215.00	45.00
2.13	5.00	10.00	18.00	12.00	215.00	48.00
	5.00	10.00	18.00	13.50	210.00	48.00
2.14	5.00	8.50	17.50	14.00	205.00	48.00
	5.00	11.50			200.00	48.00
2.15	4.00	11.50	21.00	15.00	205.00	46.00
	4.50	11.50	18.00	15.00	200.00	45.00
2.16	4.50	8.50	19.50	15.00	210.00	46.00
	4.00	11.00	18.50	15.00	210.00	47.00
2.17	3.50	8.50	18.00	13.50	202.00	46.00
	4.50	8.50	19.50	15.00	205.00	46.00
2.18			22.50	14.50	195.00	45.00
	3.00	8.50	22.50	14.50	195.00	43.00
2.19	7.00	7.00	17.00	11.00	195.00	44.00
	7.00	11.00	17.00	11.00	202.00	44.00
2.20	6.00	11.50	18.00	13.50	200.00	49.00
	7.50	9.50	13.50	12.00	198.00	43.00
2.21	5.00	7.00	17.00	10.00	205.00	46.00
	5.00	10.00	17.00	10.00	205.00	49.00
2.22	3.00	8.50	22.00	14.00	220.00	49.00
	3.50	11.50	18.50	13.50	215.00	49.00
2.23	6.50	10.00	18.00	14.00	205.00	45.00
					198.00	45.00
2.24	5.00	8.50	21.00	15.00	200.00	43.00
	3.50	10.00	22.50	16.50	202.00	45.00
2.25	5.00	6.50	18.00	15.00	205.00	44.00
	6.50	11.50	20.00	15.00	205.00	43.00
MEAN	5.02	9.53	18.75	13.70	207.78	46.38
S.D.	1.27	1.73	2.26	1.58	8.81	2.35

CASE NO.	**22SD**	**22DD**	**22SL**	**22DL**	**22CIR**	**22MC**
2.1	3.00	11.50	19.50	15.00	210.00	46.00
	3.00	11.00	22.50	18.00	210.00	46.00
2.2	6.00	11.50		15.00	225.00	47.00
	5.00	11.50	19.50	15.00	220.00	47.00
2.3	3.00	10.00	21.00	16.50	230.00	54.00
					220.00	55.00
2.4	3.50	9.50	19.50	15.00	235.00	49.00
	3.50	10.00	22.50	16.50	230.00	53.00

2.5	6.00	11.50	21.00	15.00	225.00	42.00
	3.50	11.50	19.50	15.00	220.00	50.00
2.6	6.00	9.00	22.00	11.00	195.00	42.00
	6.00	14.00	22.00	14.00	190.00	39.00
2.7	6.00	8.00	25.00	14.00	220.00	51.00
	5.00	6.00	25.00	11.00	220.00	48.00
2.8	6.00	11.50	25.50	18.00	232.00	49.00
	3.00	13.00	22.50	15.00	227.00	48.00
2.9	4.00	13.00	18.00	15.00	210.00	48.00
	4.00	8.50	27.00	21.00	210.00	48.00
2.10	6.00	9.00	22.50	16.50	225.00	52.00
	6.00	10.00	21.00	13.50	215.00	49.00
2.11	3.00	11.50	21.00	15.00	215.00	47.00
	4.00	10.00	19.50	13.50	210.00	45.00
2.12	4.00	11.50	16.50	12.00	210.00	49.00
	5.00	8.50	16.50	12.00	220.00	48.00
2.13	5.00	11.50	19.50	15.00	230.00	42.00
	4.00	13.00	19.50	13.50	230.00	48.00
2.14	4.50	8.50	18.00	15.00	220.00	50.00
	3.00	11.50	21.00	16.50	218.00	48.00
2.15	4.00	11.50	21.00	15.00	210.00	48.00
	3.00	11.50	19.50	15.00	205.00	46.00
2.16	3.50	11.50	21.00	17.00	215.00	48.00
	3.50	11.50	21.00	15.00	215.00	48.00
2.17	3.50	11.50	19.50	15.00	202.00	44.00
	4.50	8.50	22.50	16.00	210.00	49.00
2.18			25.50	15.00	200.00	45.00
	3.50	11.50	25.50	19.50	200.00	45.00
2.19	6.00	9.00	22.00	11.00	198.00	45.00
	6.00	14.00	22.00	14.00	212.00	45.00
2.20	5.00	11.50	19.50	15.00	215.00	53.00
	6.00	11.50	18.00	15.00	200.00	48.00
2.21	5.00	8.00	25.00	14.00	218.00	54.00
	6.00	6.00	25.00	11.00	215.00	49.00
2.22	3.00	11.00	22.50	18.00	228.00	49.00
	3.00	11.50	19.50	15.00	223.00	49.00
2.23					208.00	48.00
	3.00	10.00	21.00	16.50	202.00	47.00
2.24	3.50	9.50	19.50	15.00	210.00	45.00
	3.50	10.00	22.50	16.50	205.00	45.00
2.25	3.50	11.50	21.00	15.00	205.00	45.00
	6.00	11.50	19.50	15.00	205.00	47.00
MEAN	4.38	10.60	21.33	15.02	214.56	47.68
S.D.	1.18	1.76	2.41	2.03	10.48	3.17

CASE NO.	**24SD**	**24DD**	**24SL**	**24DL**	**24CIR**	**24MC**
2.1	3.00	11.50	28.50	19.50	215.00	48.00
	3.00	11.50	23.00	16.50	215.00	48.00
2.2	5.00	11.50	18.00	14.00	230.00	48.00
	5.00	11.50	24.00	18.00	225.00	50.00
2.3	3.50	9.00	31.50	18.00	250.00	65.00
	5.00	11.00	25.50	18.00	235.00	55.00
2.4	3.50	9.50	22.50	15.00	225.00	50.00

	3.00	11.00	27.00	23.00	235.00	53.00
2.5	4.00	12.00	22.50	16.50	228.00	53.00
	3.50	11.50	20.50	18.00	226.00	52.00
2.6	6.00	11.00	21.00	14.00	200.00	43.00
	5.00	12.00	25.00	17.00	195.00	44.00
2.7	5.00	10.00			225.00	52.00
	4.00	8.00	18.00	13.00	220.00	49.00
2.8	5.00	10.00	27.00	21.00	235.00	54.00
	4.00	8.50	22.50	18.00	235.00	53.00
2.9	3.00	11.50	21.00	16.50	215.00	48.00
	3.00	10.00	22.50		218.00	48.00
2.10	5.00	10.00	24.00	18.00	240.00	62.00
	4.00	10.00	22.50	15.00	220.00	52.00
2.11	3.00	11.50	21.00	18.00	230.00	51.00
					220.00	45.00
2.12	5.00	10.00	16.50	11.50	215.00	50.00
	3.50	10.00	22.50	11.50	230.00	50.00
2.13	5.00	11.50	21.00	16.50	270.00	58.00
	4.00	11.50	24.00	16.50	230.00	58.00
2.14	6.00	11.50	22.50	16.50	230.00	54.00
	3.50	10.00	21.00	17.00	236.00	57.00
2.15	4.00	10.00	25.50	15.00	225.00	54.00
	3.00	11.00	21.00	14.00	210.00	48.00
2.16	3.00	11.50	22.50	17.00	225.00	50.00
	3.00	11.50	22.50	16.50	225.00	52.00
2.17	3.00	11.50	22.00	15.50	205.00	47.00
	3.50	8.50	22.50	18.00	216.00	51.00
2.18			31.50	22.00	220.00	62.00
	3.50	11.50	27.00	19.50	220.00	50.00
2.19	6.00	11.00	21.00	14.00	208.00	48.00
	5.00	12.00	25.00	17.00	220.00	54.00
2.20	5.00	11.50	18.00	14.00	235.00	61.00
	5.00	11.50	24.00	18.00	213.00	60.00
2.21	5.00	10.00	17.00	14.00	230.00	54.00
	4.00	8.00	18.00	13.00	230.00	51.00
2.22	3.00	11.50	23.00	16.50	240.00	50.00
	3.00	11.50	28.50	19.50	225.00	48.00
2.23	5.00	11.00	25.50	18.00	220.00	50.00
	3.50	9.00	31.50	18.00	210.00	52.00
2.24	3.50	9.50	22.50	15.00	220.00	47.00
	3.00	11.00	27.00	23.00	215.00	48.00
2.25	3.50	11.50	20.50	18.00	215.00	49.00
	4.00	12.00	22.50	16.50	218.00	52.00
MEAN	4.05	10.69	23.32	16.83	223.86	51.90
S.D.	0.94	1.10	3.46	2.58	12.47	4.60

CASE NO.	**26SD**	**26DD**	**26SL**	**26DL**	**26CIR**	**26MC**
2.1	3.00	10.50	26.00	19.50	230.00	49.00
	3.00	11.00	22.50	16.50	230.00	52.00
2.2	5.00	11.50	25.50	18.00	240.00	51.00
	3.00	11.50	25.00	17.00	250.00	44.00
2.3					280.00	
	4.00	8.50	32.00	21.00	270.00	

2.4	3.50	10.50	27.00	18.00	250.00	44.00
	3.00	11.50	31.50	26.00	260.00	55.00
2.5	3.50	11.50	25.50	19.50	243.00	55.00
	3.00	11.50			240.00	59.00
2.6	5.00	12.00	21.00	13.00	205.00	45.00
	7.00	10.00	25.00	17.00	205.00	49.00
2.7	5.00	10.00			240.00	58.00
	6.00	11.00	25.00	14.00	230.00	55.00
2.8	3.00	11.00	30.00	25.50	260.00	61.00
	3.00	10.00	33.00	24.00	255.00	61.00
2.9	3.00	12.00	30.00	22.50	230.00	53.00
	4.00	8.50	30.00	22.50	230.00	55.00
2.10	4.00	10.00	30.00	24.00	250.00	70.00
	3.50	12.50	22.50	18.00	230.00	58.00
2.11	3.00	10.00	25.50	24.00	250.00	55.00
	3.00	10.00	22.50	15.00	240.00	54.00
2.12	5.00	10.00			220.00	49.00
	3.00	10.00	25.50	19.50	230.00	55.00
2.13	5.00	11.50		16.50	280.00	66.00
	3.00	11.50	33.00	21.00	260.00	55.00
2.14	5.00	11.50			265.00	56.00
					245.00	58.00
2.15	5.00	10.00	29.00	22.50	250.00	62.00
	3.00	11.50	27.00	21.00	220.00	60.00
2.16	3.00	11.00	27.00	18.00	235.00	55.00
	3.00	11.50	24.00	19.50	235.00	58.00
2.17	3.00	10.00	30.00	24.00	210.00	50.00
	3.00	8.50	29.00	25.50	230.00	55.00
2.18					255.00	
	3.00	11.50	28.50	24.00	220.00	57.00
2.19	5.00	12.00	21.00	13.00	217.00	53.00
	7.00	10.00	25.00	17.00	240.00	58.00
2.20	3.00	11.50	25.00	17.00	263.00	73.00
	5.00	11.50	25.50	18.00	250.00	70.00
2.21	6.00	10.00			255.00	53.00
	5.00	11.00	25.00	14.00	260.00	60.00
2.22	3.00	11.00	22.50	16.50	250.00	54.00
	3.00	10.50	26.00	19.50	232.00	51.00
2.23	4.00	8.50	32.00	21.00	242.00	66.00
					225.00	60.00
2.24	3.50	10.50	27.00	18.00	230.00	55.00
	3.00	11.50	31.50	26.00	225.00	54.00
2.25	3.00	11.50	25.50	19.50	240.00	58.00
	3.50	11.50	25.50	19.50	240.00	56.00
MEAN	3.90	10.75	26.80	19.65	240.84	56.17
S.D.	1.10	0.99	3.30	3.66	17.36	6.17

CASE NO.	**28SD**	**28DD**	**28SL**	**28DL**	**28CIR**	**28MCD**
2.1	3.00	9.00	27.00	18.00	245.00	45.00
					270.00	58.00
2.2	5.00	12.00	25.50	18.00	280.00	54.00
	4.00	8.50	30.00	24.00	285.00	

2.3						
2.4	3.50	12.00	30.00	28.50	280.00	65.00
	3.00	11.50		27.00	280.00	66.00
2.5	3.00	12.00	30.00	24.00	273.00	75.00
	3.00	10.00			270.00	68.00
2.6	3.00	13.00	27.00	17.00	230.00	50.00
	5.00	10.00	28.00	22.00	230.00	67.00
2.7					260.00	68.00
					270.00	54.00
2.8					280.00	68.00
	2.50	8.50	31.50	27.00	275.00	66.00
2.9					270.00	60.00
					258.00	65.00
2.10	3.00	11.50	33.00	25.50	255.00	67.00
	3.00	11.50	31.50	24.00	260.00	69.00
2.11					260.00	68.00
	3.00	11.50	30.00	19.50	265.00	65.00
2.12	3.50	10.00	27.00	22.50	240.00	55.00
	3.00	10.00	25.50	22.50	250.00	63.00
2.13	3.00	10.00		18.00	280.00	66.00
					270.00	67.00
2.14	3.50	10.00	30.00	19.00	268.00	63.00
					255.00	66.00
2.15	5.00	10.00	30.00	22.00	270.00	72.00
					240.00	60.00
2.16	2.50	10.00	35.00	23.00	240.00	60.00
					250.00	65.00
2.17	2.50	11.50		25.50	250.00	67.00
	3.00	7.00	30.00	25.50	260.00	65.00
2.18					260.00	
2.19	3.00	13.00	27.00	1.00	235.00	63.00
	5.00	10.00	28.00	22.00	265.00	68.00
2.20	4.00	8.50	30.00	24.00	260.00	73.00
	5.00	12.00	25.50	18.00	270.00	75.00
2.21					260.00	69.00
					270.00	71.00
2.22					270.00	59.00
	3.00	9.00	27.00	18.00	245.00	60.00
2.23					270.00	
					260.00	
2.24	3.50	12.00	30.00	28.50	265.00	66.00
	3.00	11.50		27.00	260.00	65.00
2.25	3.00	12.00	30.00	24.00	260.00	60.00
					260.00	60.00
MEAN	3.41	10.58	29.10	22.53	261.20	64.29
S.D.	0.79	1.47	2.40	3.62	13.60	6.30

APPENDIX 4.1. DATA RECORDED FROM AIR TENDINOGRAMS, ULTRASONOGRAPHS AND POST-MORTEM SPECIMENS OBTAINED FROM TWELVE NORMAL LIMBS.

CASE NO.	4.1		4.2		4.3		4.4		4.5		4.6	
LIMB	L	R	L	R	L	R	L	R	L	R	L	R
RA	45	47	48	52	38	48	43	43	43	45	41	43
ULA	37	34	53	48	44	44	37	40	35	34	35	35
UTA	33	34	49	49	44	43	40	38	34	33	35	34
RB	15	13	18	16	10	12	13	11	11	15	10	12
ULB	21	22	25	21	21	24	23	22	18	19	17	26
UTB	18	14	29	20	16	17	14	18	16	13	15	15
RC	30	28	32	34	33	29	29	31	30	30	30	29
RS1		6	5			6	6	6	6		6	6
ULS1	7	3	9	6		5	4	5	4	4	5	6
UTS1	5	4	6	6		5	5	6	5	3	4	5
PS1	6	6	6			5	7	7	5	5	5	5
RS2												
ULS2	5	4	6	4		5	3	4	4	5	3	4
UTS2	4	2	5	3		2	5	4	3	3	4	3
PS2	4	5	4			3	5	5	4	4	3	4
RD1	10	9	13	13		13	12	13	11		11	13
ULD1	9	7	12	11	12	8	8	12	9	8	8	11
UTD1	9	7	12	10	9	9	9	10	8	8	8	8
PD1	10	12	11	11	11	12					11	11
RD2	13	15	15									
ULD2	10	9	9	10	11	10	8	8	9	9	7	9
UTD2	9	6	12	10	9	10	7	8	10	9	6	6
PD2	10	10	10	10	11	11					10	11

APPENDIX 4.2. DATA RECORDED FROM AIR TENINOGRAMS AND ULTRASONOGRAPHS OBTAINED FROM TEN LIMBS WITH SUPERFICIAL DIGITAL FLEXOR TENDON INJURY AND FROM POST-MORTEM SPECIMENS FROM FOUR OF THESE LIMBS.

CASE NO.	4.7		4.8	4.9		4.10		4.11	4.12	4.13
LIMB	L	R	L	L	R	L	R	R	R	R
RA	38	47	44	51	48	48	60	57	39	62
ULA	43	49	37	43	39	46	54	44	47	59
UTA	41	48	35	49	49	45	53	47	45	52
RB	14	10	11	15	11	15	16	16	12	17
ULB	25	21	20	17	17	20	27	24	23	39
UTB	29	21	17	19	20	25	29	19	25	23
RC	37	37	27	30	31	32	31	31	31	34
RS1	6	15	6	10	10					18
ULS1	7	8	6	6	6	8	11	7	8	12
UTS1	8	10	6	6	6	9	11	10	8	11
PS1	6	15					9	16		
RS2			6		2					
ULS2	4	11	4	6	4	5	6	7	10	8
UTS2	5	5	6	4	7	5	7	5	9	7
PS2	4	6				7	8			
RD1	14	11	13	15	13	12				13
ULD1	8	13	7	11	10	10	13	10	10	11
UTD1	14	11	8	11	9	10	11	9	13	12
PD1		11					11	11		
RD2			11							
ULD2	8	11	6	9	7	9	11	11	10	8
UTD2	9	12	6	7	7	9	12	12	8	11
PD2		10					12	12		

ABREVIATIONS USED IN APPENDICES 4.1 AND 4.2.

RA = total dorsal-palmar soft tissue thickness at the level of the distal end of the second and fourth metacarpal bones recorded from air tendinograms.

ULA = total dorsal-palmar soft tissue thickness at the level of the distal end of the second and fourth metacarpal bones recorded from longitudinal ultrasonographs.

UTA = total dorsal-palmar soft tissue thickness at the level of the distal end of the second and fourth metacarpal bones recorded from transverse ultrasonographs.

RB = total dorsal-palmar soft tissue thickness at the level of the proximal sesamoids recorded from air tendinograms.

ULB = total dorsal-palmar soft tissue thickness at the level of the proximal sesamoids recorded from longitudinal ultrasonographs.

UTB = total dorsal-palmar soft tissue thickness at the level of the proximal sesamoids recorded from transverse ultrasonographs.

RC = dorsal-palmar thickness of the third metacarpal bone at the level of the distal end of the second and fourth metacarpal bones recorded from air tendinograms.

RS1 = dorsal-palmar thickness of the superficial digital flexor tendon at the level of the distal end of the second and fourth metacarpal bones recorded from air tendinograms.

ULS1 = dorsal-palmar thickness of the superficial digital flexor tendon at the level of the distal end of the second and fourth metacarpal bones recorded from longitudinal ultrasonographs.

UTS1 = dorsal-palmar thickness of the superficial digital flexor tendon at the level of the distal end of the second and fourth metacarpal bones recorded from transverse ultrasonographs.

PS1 = dorsal-palmar thickness of the superficial digital flexor tendon at the level of the distal end of the second and fourth metacarpal bones recorded from post-mortem specimens.

RS2 = dorsal-palmar thickness of the superficial digital flexor tendon at the level of the proximal sesamoids recorded from air tendinograms.

ULS2 = dorsal-palmar thickness of the superficial digital flexor tendon at the level of the proximal sesamoids recorded from longitudinal ultrasonographs.

UTS2 = dorsal-palmar thickness of the superficial digital flexor tendon at the level of the proximal sesamoids recorded from transverse ultrasonographs.

PS2 = dorsal-palmar thickness of the superficial digital flexor tendon at the level of the proximal sesamoids recorded from post-mortem specimens.

RD1 = dorsal-palmar thickness of the deep digital flexor tendon at the level of the distal end of the second and fourth metacarpal bones recorded from air tendinograms.

ULD1 = dorsal-palmar thickness of the deep digital flexor tendon at the level of the distal end of the second and fourth metacarpal bones recorded from longitudinal ultrasonographs.

UTD1 = dorsal-palmar thickness of the deep digital flexor tendon at the level of the distal end of the second and fourth metacarpal bones recorded from transverse ultrasonographs.

PD1 = dorsal-palmar thickness of the deep digital flexor tendon at the level of the distal end of the second and fourth metacarpal bones recorded from post-mortem specimens.

RD2 = dorsal-palmar thickness of the deep digital flexor tendon at the level of the proximal sesamoids recorded from air tendinograms.

ULD2 = dorsal-palmar thickness of the deep digital flexor tendon at the level of the proximal sesamoids recorded from longitudinal ultrasonographs.

UTD2 = dorsal-palmar thickness of the deep digital flexor tendon at the level of the proximal sesamoids recorded from transverse ultrasonographs.

PD2 = dorsal-palmar thickness of the deep digital flexor tendon at the level of the proximal sesamoids recorded from post-mortem specimens.

APPENDIX 5.1. CASE DETAILS, HISTORY, ULTRASONOGRAPHIC FINDINGS AND OUTCOME IN 90 HORSES WITH SUPERFICIAL DIGITAL FLEXOR TENDON INJURY.

CASE NO. (AGE, SEX, HISTORY OF SDFT INJURY, FORELIMB AFFECTED, SEVERITY, OUTCOME).

5.1 (5 y.o., gelding, no previous injury, right, moderate, 10 months off, training).

	WEEK	LOCATION			L	CS%	TE	ECHO	BORD	LIN	PT	
	1	-	+	+	120	65	+	1	4	0	-	
	2	-	+	+	120	65	+	1	4	0	-	
	3	-	+	+	120	65	+	1	4	0	-	
	6	-	+	+	120	65	+	3	4	0	-	
	12	-	+	+	120	65	+	3	4	1	-	
	24	-	+	-	100	65	+	2	2	3	-	
	36	-	+	-	100	65	+	2	1/2	3	-	#m

5.2 (6 y.o., mare, bilateral, moderate/moderate, retired)

	WEEK	LOCATION			L	CS%	TE	ECHO	BORD	LIN	PT
left	2	-	+	-	80	60	+	1	4	0	-
	7	-	+	-	80	60	+	1	4	0	-
	9	-	+	-	80	60	+	1	3	0	-
	12	-	+	-	80	60	+	2	3	1	+/-
	26	-	+	-	80	60	+	2 + 5	2	2	+/-
right	2	-	-	+	100	75	+	1	4	0	-
	7	-	-	+	100	75	+	1	4	0	-
	9	-	-	+	100	75	+	1	3	0	-
	12	-	-	+	100	75	+	3 + 5	3	1	+/-
	26	-	-	+	100	75	+	2 + 5	3	2	+/-

5.3 (8 y.o., mare, previous injury, right, severe, retired)

	WEEK	LOCATION			L	CS%	TE	ECHO	BORD	LIN	PT
	3	+	+	+	220	100	+	3	*	0	-
	26	+	+	+	220	100	+	2	*	1	+
	36	+	+	+	220	100	+	2 + 5	*	2	+
	52	+	+	+	220	100	+	2 + 5	*	2	+
	60	+	+	+	220	100	+	2 + 5	*	3	+

5.4 (9 y.o., gelding, right, severe, 24 months off, raced 3 times, recurred).

3	+	+	+	220	100	+	3	*	0	-	
12	+	+	+	220	100	+	3	*	0	-	
26	+	+	+	220	100	+	3 + 5	*	1	+	
36	+	+	+	220	100	+	3 + 5	*	2	+	
40	+	+	+	220	100	+	4 + 5	3	2	+	#d
52	+	+	+	220	100	+	4 + 5	3	2	+	#d
60	+	+	+	220	100	+	4 + 5	3	3	+	#d
68	+	+	+	220	100	+	4 + 5	2	3	+	#d
74	+	+	+	220	100	+	2 + 5	2	3	+	
80	+	+	+	220	100	+	2 + 5	1	3	+	
92	+	+	+	220	100	+	5	0	4	+	
102	+	+	+	220	100	+	5	0	4	+	
110	+	+	+	220	100	+	5	0	4	+	

5.5 (10 y.o., gelding, previous injury, right, severe, retired).

3	+	+	+	220	100	+	3	*	0	+
12	+	+	+	220	100	+	3	*	0	+
26	+	+	+	220	100	+	3 + 5	*	1	+

5.6 (12 y.o., mare, no previous injury, bilateral, moderate/moderate, retired).

left	1	-	+	-	100	60	+	1	4	0	-
	8	-	+	-	100	60	+	3	4	0	-
	12	-	+	-	100	60	+	3	3	1	-
	24	-	+	-	100	60	+	2	2	2	-
	36	-	+	-	100	60	+	2	1	3	-
right	1	-	+	-	80	40	+	1	4	0	-
	8	-	+	-	80	40	+	2	4	0	-
	12	-	+	-	80	40	+	2	3	1	-
	24	-	+	-	80	*	+	2	1	4	-
	36	-	+	-	80	*	+	2	1	4	-

5.7 (4 y.o., gelding, previous injury, bilateral, severe/mild, 9 months off, raced 3 times).

left	1	-	+	-	60	30	-	2	3	0	-	
	5	-	+	-	60	30	-	2	3	0	-	
	12	-	+	-	60	30	-	2	3	1	-	
	37	-	+	-	80	50	+	2	3	0	-	
	52	-	+	-	80	*	+	2	1	4	-	
	72	-	+	-	80	*	+	2	1	4	-	
right	1	-	+	-	100	75	+	1	4	0	-	
	5	-	+	-	100	75	+	1	4	0	-	
	12	-	+	-	100	75	+	2 + 5	3	1	-	
	37	+	+	+	200	90	+	3 + 5	3	1	+/-	
	52	+	+	+	200	100	+	4 + 5	1	2	+	
	72	+	+	+	200	100	+	4 + 5	2	3/4	+	#m

5.8 (8 y.o., mare, no previous injury, right, severe, outcome unknown).

	1	+	+	+	200	100	+	3	*	0	+	
	2	+	+	+	200	100	+	3	*	0	+	
	5	+	+	+	200	100	+	3	*	0	+/-	
	12	+	+	+	200	100	+	3	*	0	+/-	
	26	+	+	+	200	100	+	4 + 5	3	1	+/-	#d

5.9 (9 y.o., gelding, previous injury, right, mild, 9 months off, raced once).

(1)	8	-	-	+	40	25	+	1	3	1	+	
	12	-	-	+	40	25	+	2	3	2	+	
	14	-	-	+	40	25	+	2	2	2	+	
	16	-	-	+	40	25	+	2	2	2	+	
	26	-	-	+	30	*	+	2	1	4	+	

5.10 (10 y.o., mare, left, severe, retired).

	4	+	+	+	200	100	+	3	*	0		#1
	6	+	+	+	200	100	+	3	*	0		
	8	+	+	+	200	100	+	3	*	0	+	
	12	+	+	+	200	100	+	3 + 5	*	0	+	
	26	+	+	+	200	100	+	4 + 5	3	1	+	
	36	+	+	+	200	100	+	4 + 5	3	1	+	
	52	+	+	+	200	100	+	2 + 5	*	3	+	

5.11 (6 y.o., gelding, bilateral, severe/mild, retired).

left	2	-	+	+	140	85	+	1	4	0	-
	4	-	+	+	140	85	+	2	4	0	-
	8	-	+	+	140	85	+	2	3	0	-
	12	-	+	+	140	85	+	4 + 5	3	1	+
	26	-	+	+	140	85	+	4 + 5	2	2	+
right	2	-	-	+	80	70	+	1	4	0	-
	7	-	-	+	80	70	+	1	4	0	-
	9	-	-	+	80	70	+	1	3	0	-
	12	-	-	+	80	70	+	3 + 5	3	1	+/-
	26	-	-	+	80	70	+	4 + 5	2	2	+/-

5.12 (6 y.o., mare, no previous injury, left, mild 7 months off, trained, recurred).

1	-	+	-	40	25	-	2	3	2	-
4	-	+	-	40	25	-	2	3	2	-
12	-	+	-	40	25	-	2	1	3	-
16	-	+	-	*	*	-		*	4	-

5.13 (4 y.o., gelding, no previous injury, left, mild 10 months off, raced 3 times).

1	-	+	+	80	40	+	1	4	0	-
4	-	+	+	80	40	+	2	4	0	-
26	-	+	+	80	40	+	2	2	1	-
36	-	+	+	80	40	+	*	*	4	-

5.14 (6 y.o., gelding, bilateral, severe/severe, 18 months off, trained, recurred).

left	52	+	+	+	220	100	+	4	+	5	*	3	+/-	
	56	+	+	+	220	100	+	4	+	5	*	3	+/-	
	62	+	+	+	220	100	+	4	+	5	*	3	+/-	
	70	+	+	+	220	100	+	4	+	5	*	3	+/-	
	78	+	+	+	220	100	+	4	+	5	*	3	+/-	
	84	+	+	+	220	100	+	4	+	5	*	3	+/-	
	90	+	+	+	220	100	+	4	+	5	*	3	+/-	
	120	+	+	+	220	100	+	4	+	5	*	3	+/-	
right	52	+	+	+	220	100	+	4	+	5	*	3	+/-	
	56	+	+	+	220	100	+	4	+	5	*	3	+/-	
	62	+	+	+	220	100	+	4	+	5	*	3	+/-	
	70	+	+	+	220	100	+	4	+	5	*	3	+/-	
	78	+	+	+	220	100	+	4	+	5	*	3	+/-	
	84	+	+	+	220	100	+	4	+	5	*	3	+/-	
	90	+	+	+	220	100	+	4	+	5	*	3	+/-	
	120	+	+	+	220	100	+	4	+	5	*	3	+/-	

5.15 (4 y.o., gelding, bilateral, severe/mild 20 months off, raced 3 times).

left	3	+	+	+	220	100	+	3			*	0	-	
	26	+	+	+	220	100	+	2			*	1	+	
	36	+	+	+	220	100	+	2	+	5	3	2	+	#d
	52	+	+	+	220	100	+	2	+	5	3	2	+	#d
	60	+	+	+	220	100	+	2	+	5	2	3	+	#d
	84	+	+	+	220	100	+	5			*	4	+	
right	3	-	+	-	80	40	+	2			4	0	+	
	26	-	+	-	80	40	+	*			2	3	+	
	36	-	+	-	80	40	+	*			1	4	+	
	52	-	+	-	80	40	+	*			1	4	+	
	60	-	+	-	80	40	+	*			1	4	+	
	84	-	+	-	80	40	+	*			1	4	+	

5.16 (5 y.o., gelding, right, severe/mild, retired).

left	1	+	+	+	220	100	+	3			*	0	+	
	4	+	+	+	220	100	+	3			*	0	+	
	12	+	+	+	220	100	+	3			*	0	+	
	26	+	+	+	220	100	+	4	+	5	*	1	+	
	36	+	+	+	220	100	+	4	+	5	3	2	+	#d
	52	+	+	+	220	100	+	4	+	5	3	2	+	#d
right	1	-	+	-	80	40	+	2			4	0	+	
	4	-	+	-	80	40	+	2			4	0	+	
	12	-	+	-	80	40	+	2			3	1	+	
	26	-	+	-	80	40	+	*			2	3	+	
	36	-	+	-	80	40	+	*			1	4	+	
	52	-	+	-	80	40	+	*			1	4	+	

5.17 (8 y.o., mare, right, severe, outcome unknown).

	4	+	+	+	220	100	+	3			*	0	+	#2
	8	+	+	+	220	100	+	3			*	0	+	
	12	+	+	+	220	100	+	3			*	0	+	

5.18 (6 y.o., gelding, previous injury, bilateral, severe/moderate, died).

left	1	+	+	+	220	100	+	3	*	0		
	4	+	+	+	220	100	+	3	*	0	+	
	8	+	+	+	220	100	+	3	*	0	+	
	12	+	+	+	220	100	+	3	*	0	+	
	26	+	+	+	220	100	+	4 + 5	*	1	+	#d
	52	+	+	+	220	100	+	4 + 5	*	3	+	#d
	72	+	+	+	220	100	+	4 + 5	*	3	+	#d
right	1	-	+	+	120	65	+	1	4	0	-	
	4	-	+	+	120	65	+	1	4	0	-	
	8	-	+	+	120	65	+	1	4	0	-	
	12	-	+	+	120	65	+	3	4	1	-	
	26	-	+	-	100	65	+	2	1/2	3	-	#m
	52	-	+	-	100	*	+	5	*	4	-	#m
	72	-	+	-	100	*	+	5	*	4	-	#m

5.19 (8 y.o., mare, previous injury, bilateral, severe/severe, 18 months off, raced once, recurred).

left	8	+	+	+	220	100	+	3	*	0	+	
(2)	12	+	+	+	220	100	+	3	*	0	+	
	26	+	+	+	220	100	+	4 + 5	*	1	+	#d
	52	+	+	+	220	100	+	4 + 5	*	3	+	#d
	72	+	+	+	220	100	+	4 + 5	*	3	+	#d
right	8	+	+	+	220	100	+	3	*	0	+	#2
	12	+	+	+	220	100	+	3	*	0	+	
	26	+	+	+	220	100	+	4 + 5	*	1	+	#d
	52	+	+	+	220	100	+	4 + 5	*	3	+	#d
	72	+	+	+	220	100	+	4 + 5	*	3	+	#d

5.20 (6 y.o., mare, bilateral, moderate/moderate, retired).

left	6	-	+	+	140	75	+	1	4	0	+/-
	7	-	+	+	140	75	+	1	4	0	+/-
	8	-	+	+	140	75	+	3	4	0	+/-
	9	-	+	+	140	75	+	3	3	0	+/-
	10	-	+	+	140	75	+	3	3	0	+/-
	14	-	+	+	140	75	+	4 + 5	3	1	+/-
	26	-	+	+	140	75	+	4 + 5	2	2	+/-
	37	-	+	+	140	75	+	4 + 5	2	2	+/-
right	6	-	+	+	100	60	+	1	4	0	+/-
	7	-	+	+	100	60	+	1	4	0	+/-
	8	-	+	+	100	60	+	3	4	0	+/-
	9	-	+	+	100	60	+	3	3	0	+/-
	10	-	+	+	100	60	+	3	3	0	+/-
	14	-	+	+	100	60	+	4	3	1	+/-
	26	-	+	+	100	60	+	4 + 5	2	2	+/-
	37	-	+	+	100	60	+	4 + 5	2	2	+/-

5.21 (7 y.o., gelding, no previous injury, left, moderate, 12 months off, training).

	3	-	+	+	180	85	+	3	4	0	+
	4	-	+	+	180	85	+	3	4	0	+
	7	-	+	+	180	85	+	3	4	0	+
	8	-	+	+	180	85	+	3	3	0	+
	12	-	+	+	180	85	+	4	3	1	+
	26	-	+	+	180	85	+	4 + 5	2	2	+
	37	-	+	+	180	85	+	4 + 5	1	2	+
	52	-	+	+	180	85	+	4 + 5	1	3	+
	72	-	+	+	180	*	+	2 + 5	*	4	+

5.22 (4 y.o., gelding, no previous injury, left, moderate, 12 months off, raced twice, recurred).

left	1	+	+	-	120	75	+	1	4	0	-
	2	+	+	-	120	75	+	1	4	0	-
	3	+	+	-	120	75	+	1	4	0	-
	4	+	+	-	120	75	+	3	3	0	-
	12	+	+	-	120	75	+	3	3	1	-
	26	+	+	-	120	75	+	4	2	3	+/-
	36	+	+	-	120	75	+	3	3	1	+/-
right	1	-	+	-	60	25	-	2	3	2	-
	2	-	+	-	60	25	-	2	3	2	-
	3	-	+	-	60	25	-	2	3	2	-
	4	-	+	-	60	25	-	2	3	2	-
	12	-	+	-	60	25	-	2	1	3	-
	26	-	+	-	*	*	-		*	4	-

5.23 (10 y.o., gelding, no previous injury, left, severe 12 months off, training).

(3)	1	+	+	+	220	100	+	2		0	+	#3
	2	+	+	+	220	100	+	2		0	+	#3
	3	+	+	+	220	100	+	2		0	+	#3
	4	+	+	+	220	100	+	3 + 5		0	+	#4
	8	+	+	+	220	100	+	3 + 5		0	+	#4
	12	+	+	+	220	100	+	3 + 5		0	+	
	26	+	+	+	220	100	+	4 + 5		1	+	#d
	36	+	+	+	220	100	+	4 + 5	3	2	+	#d
	52	+	+	+	220	100	+	4 + 5	3	3	+	#d
	64	+	+	+	220	100	+	4 + 5	2	3	+	#d

5.24 (9 y.o., gelding, no previous injury, left, moderate, outcome unknown).

	1	-	+	+	120	75	+	1	4	0	-
	2	-	+	+	120	75	+	1	4	0	-
	3	-	+	+	120	75	+	1	4	0	-
	4	-	+	+	120	75	+	3	3	0	-
	12	-	+	+	120	75	+	3	3	1	-
	26	-	+	+	120	75	+	4 + 5	2	2	+/-
	36	-	+	+	120	75	+	4 + 5	1	3	+/-

5.25 (8 y.o., gelding, left, severe, outcome unknown).

	3	+	+	+	220	100	+	3	*	0	-	
	26	+	+	+	220	100	+	4	*	1	+	
	36	+	+	+	220	100	+	4 + 5	*	2	+	
	52	+	+	+	220	100	+	2 + 5	*	3	+	

5.26 (6 y.o., gelding, bilateral, moderate/moderate, died, unrelated cause).

left	1	+	+	+	180	70	+	1	4	0	-	
	4	+	+	+	180	70	+	3	4	0	-	
	12	+	+	+	180	70	+	3	3	0	-	
right	1	+	+	+	180	60	+	1	4	0	-	
	4	+	+	+	180	60	+	3	4	0	-	
	12	+	+	+	180	60	+	4 + 5	3	0	-	

5.27 (7 y.o., mare, bilateral, moderate/moderate, retired).

left	1	-	+	+	120	65	+	1	4	0	-	
	2	-	+	+	120	65	+	1	4	0	-	
	3	-	+	+	120	65	+	1	4	0	-	
	8	-	+	+	120	65	+	3	4	0	-	
	12	-	+	+	120	65	+	3	4	1	-	
	24	-	+	-	100	65	+	2	2	3	-	
	36	-	+	-	100	65	+	2	1/2	3	-	#m
	52	-	+	-	100	65	+	5	1	4	-	
right	1	-	+	+	120	65	+	1	4	0	-	
	2	-	+	+	120	65	+	1	4	0	-	
	3	-	+	+	120	65	+	1	4	0	-	
	8	-	+	+	120	65	+	3	4	0	-	
	12	-	+	+	120	65	+	3	4	1	-	
	24	-	+	-	100	65	+	2 + 5	2	3	-	
	36	-	+	-	100	65	+	2 + 5	1	3	-	
	52	-	+	-	100	65	+	5	1	4	-	

5.28 (6 y.o., gelding, left, severe, retired).

	52	+	+	+	220	100	+	2 + 5	*	3	+	

5.29 (5 y.o., gelding, previous injury, bilateral, severe/moderate, 24 months off, raced twice, recurred).

left	2	+	+	+	220	100	+	3	*	0	+	
	4	+	+	+	220	100	+	3	*	0	+	
	8	+	+	+	220	100	+	3	*	0	+	
	12	+	+	+	220	100	+	3	*	0	+	
	16	+	+	+	220	100	+	3 + 5	*	1	+	
	18	+	+	+	220	100	+	3 + 5	*	1	+	
	20	+	+	+	220	100	+	3 + 5	*	1	+	
	26	+	+	+	220	100	+	4 + 5	*	1	+	
	52	+	+	+	220	100	+	4 + 5	3	2	+	#d
	78	+	+	+	220	100	+	4 + 5	3	2	+	#d
	82	+	+	+	220	100	+	4 + 5	2	3	+	#d
	84	+	+	+	220	100	+	4 + 5	3	3	+	#d
	88	+	+	+	220	100	+	4 + 5	1	3	+	#d
right	2	+	+	+	160	70	+	1	4	0	-	
	4	+	+	+	160	70	+	1	4	0	-	
	8	+	+	+	160	70	+	1	4	0	-	
	12	+	+	+	160	70	+	1	4	1	-	
	16	+	+	+	160	70	+	3	3	1	-	
	18	+	+	+	160	70	+	3	3	2	-	
	20	+	+	+	160	70	+	3	2	2	-	
	26	+	+	+	160	70	+	4	2	2	-	
	52	+	+	+	160	70	+	4	1	3	-	
	78	+	+	+	*	*	+	4	1	3	-	
	82	+	+	+	*	*	+	4	1	4	-	
	84	+	+	+	*	*	+	4	*	4	-	
	88	+	+	+	*	*	+	4	*	4	-	

5.30 (7 y.o., gelding, previous injury, bilateral, severe/moderate, 12 months off, raced once, recurred).

	1	+	+	+	220	100	+	2	*	2	+
	4	+	+	+	220	100	+	2	*	2	+
	12	+	+	+	220	100	+	2	*	3	+
	26	+	+	+	220	100	+	2	*	3	+
	1	+	+	+	180	85	+	1	4	0	+
	4	+	+	+	180	85	+	1	4	0	+
	12	+	+	+	180	85	+	2	3	2	+
	26	+	+	+	180	85	+	2	1	3	+

5.31 (5 y.o., gelding, no previous injury, left, severe, retired).

right	1	-	+	+	180	90	+	3	4	0	+
	2	-	+	+	180	90	+	3	4	0	+
	4	-	+	+	180	90	+	3	4	0	+
	8	-	+	+	180	90	+	3	3	0	+
	12	-	+	+	180	90	+	4	3	1	+
	26	-	+	+	180	90	+	4 + 5	2	2	+
	37	-	+	+	180	90	+	4 + 5	1	2	+
	52	-	+	+	180	90	+	4 + 5	1	3	+
	72	-	+	+	180	*	+	2 + 5	*	4	+

5.32 (7 y.o., gelding, previous injury, bilateral, severe/moderate, retired).

left	2	+	+	+	200	100	+	3	*	0	+	
	4	+	+	+	200	100	+	3	*	0	+	
	8	+	+	+	200	100	+	3	*	0	+	
	26	+	+	+	200	100	+	4 + 5*		2	+	
	52	+	+	+	200	100	+	4 + 5*		3	+	
	72	+	+	+	200	100	+	2 + 5*		4	+	
right	2	-	+	+	140	60	+	1	4	0	+	
	4	-	+	+	140	60	+	1	4	0	+	
	8	-	+	+	140	60	+	3	3	0	+	
	26	-	+	+	140	60	+	4	2	3	+	
	52	-	+	+	140	60	+	1	4	1	+	#5
	72	-	+	+	140	60	+	4	2	3	+	

5.33 (7 y.o., gelding, right, moderate, retired).

(4)	78	+	+	+	220	100	+	2 + 5	*	3	+	#6
	82	+	+	+	220	100	+	2 + 5	*	3	+	

5.34 (6 y.o., mare, no previous injury, bilateral, mild/mild, outcome unknown).

left	4	-	+	-	60	30	+	2	4	0	+	
	6	-	+	-	60	30	+	2	4	0	+	
	7	-	+	-	60	30	+	2	3	1	+	
	8	-	+	-	60	30	+	2	3	1	+	
	10	-	+	-	60	30	+	2	2	2	+	
	12	-	+	-	60	30	+	2	2	2	+	
	26	-	+	-	60	30	+	2 + 5	1	2	+/-	
right	4	-	+	-	50	25	+	2	3	0	+	
	6	-	+	-	50	25	+	2	3	0	+	
	7	-	+	-	50	25	+	2	3	1	+	#7
	8	-	+	-	50	25	+	2	3	1	+	
	10	-	+	-	50	25	+	2	2	2	+	
	12	-	+	-	50	25	+	2	2	2	+	
	26	-	+	-	50	25	+	2 + 5	1	2	+/-	

5.35 (4 y.o., gelding, left, severe, retired).

	1	+	+	+	220	100	+	2	*	0	+	#3
	2	+	+	+	220	100	+	2	*	0	+	#3
	3	+	+	+	220	100	+	2	*	0	+	#3
	4	+	+	+	220	100	+	2	*	0	+	#3
	8	+	+	+	220	100	+	2 + 5	*	0	+	#4
	12	+	+	+	220	100	+	2 + 5	*	0	+	#4
	26	+	+	+	220	100	+	4 + 5	*	1	+	
	36	+	+	+	220	100	+	4 + 5	*	2	+	
	52	+	+	+	220	100	+	4 + 5	*	3	+	

5.36 (7 y.o., gelding, bilateral, severe/mild, retired).

1	-	+	+	180	90	+	3	4	0	+	
2	-	+	+	180	90	+	3	4	0	+	
4	-	+	+	180	90	+	3	4	0	+	
8	-	+	+	180	90	+	3 + 5	3	0	+	
12	-	+	+	180	90	+	3 + 5	3	1	+	
26	-	+	+	180	90	+	4 + 5	2	2	+	
37	-	+	+	180	90	+	4 + 5	1	2	+	
52	-	+	+	180	90	+	4 + 5	1	3	+	
72	-	+	+	180	*	+	2 + 5	*	4	+	
1	-	+	-	50	25	-	2	3	2	-	
4	-	+	-	50	25	-	2	3	2	-	
12	-	+	-	50	25	-	2	1	3	-	
18	-	+	-	*	*	-		*	4	-	
26	-	+	-	*	*	-		*	4	-	
37	-	+	-	*	*	-		*	4	-	
52	-	+	-	*	*	-		*	4	-	
72	-	+	-	*	*	-		*	4	-	

5.37 (6 y.o., gelding, previous injury, right, severe, retired).

1	-	+	+	180	90	+	3	4	0	+	#2
2	-	+	+	180	90	+	3	4	0	+	
26	-	+	+	180	90	+	4 + 5	2	2	+	
37	-	+	+	180	90	+	4 + 5	1/3	2	+	#m
52	-	+	+	180	90	+	4 + 5	1	3	+	

5.38 (6 y.o., gelding, no previous injury, left, mild, 11 months off, raced 5 times).

1	-	+	-	50	25	-	2	3	2	-
4	-	+	-	50	25	-	2	3	2	-
12	-	+	-	50	25	-	2	1	3	-
18	-	+	-	*	*	-		*	4	-
26	-	+	-	*	*	-		*	4	-

5.39 (5 y.o., mare, left, severe, 26 months off, raced 3 times).

2	+	+	+	180	95	+	3	4	0	+	
3	+	+	+	180	95	+	3	4	0	+	
4	+	+	+	180	95	+	3	4	0	+	
8	+	+	+	180	95	+	3	4	0	+	
12	+	+	+	180	95	+	3 + 5	3	1	+	
26	+	+	+	180	95	+	3 + 5	3	2	+	
36	+	+	+	180	95	+	4 + 5	2/3	2	+	#d
52	+	+	+	180	95	+	4 + 5	2/3	3/2	+	#d
64	+	+	+	180	95	+	4 + 5	2/3	3/2	+	#d
80	+	+	+	180	95	+	5	*	4	+	

5.40 (8 y.o., gelding, right, severe, retired).

12	+	+	+	220	100	+	4 + 5	*	1	+
26	+	+	+	220	100	+	4 + 5	*	2	+
36	+	+	+	220	100	+	4 + 5	*	2	+
52	+	+	+	220	100	+	4 + 5	*	2	+

5.41 (6 y.o., gelding, previous injury, bilateral, severe/mild, 18 months off, raced 3 times).

left	1	+	+	+	220	100	+	3	*	0	+
	2	+	+	+	220	100	+	3	*	0	+
	3	+	+	+	220	100	+	3	*	0	+
	4	+	+	+	220	100	+	3	*	0	+
	8	+	+	+	220	100	+	3	*	0	+
	12	+	+	+	220	100	+	3	*	0	+
	26	+	+	+	220	100	+	3 + 5	*	1	+
	36	+	+	+	220	100	+	4 + 5	*	2	+
	52	+	+	+	220	100	+	4 + 5	*	2	+
	60	+	+	+	220	100	+	4 + 5	*	2	+
right	1	-	+	-	80	40	+	2	4	0	-
	2	-	+	-	80	40	+	2	4	0	-
	3	-	+	-	80	40	+	2	4	0	-
	4	-	+	-	80	40	+	2	4	0	-
	8	-	+	-	80	40	+	2	3	0	-
	12	-	+	-	80	40	+	2	2	1	-
	26	-	+	-	80	40	+	2	1	1	-
	36	-	+	-	80	*	+		*	4	-
	52	-	+	-	80	*	+		*	4	-
	60	-	+	-	*	*	+		*	4	-

5.42 (4 y.o., gelding, no previous injury, right, moderate, 9 months off, raced once, recurred).

1	+	+	+	140	70	+	2	3	0	+
4	+	+	+	140	70	+	1	4	0	-
12	+	+	+	140	70	+	1	3	0	+/-
26	+	+	+	140	70	+	3 + 5	2	2	+/-
36	+	+	+	140	70	+	4 + 5	2	2	+/-

5.43 (5 y.o., gelding, previous injury, right, severe, retired).

1	+	+	+	220	100	+	3	*	0	+/-
4	+	+	+	220	100	+	3	*	0	+/-
12	+	+	+	220	100	+	3 + 5	*	1	+/-
26	+	+	+	220	100	+	3 + 5	*	2	+
36	+	+	+	220	100	+	3 + 5	*	2	+
52	+	+	+	220	100	+	3 + 5	*	2	+

5.44 (5 y.o., gelding, previous injury, bilateral, moderate/moderate, 8 months off, raced twice, recurred).

left	3	-	+	+	120	40	+	2	3	0	-
	6	-	+	+	120	40	+	4	2	1	-
	12	-	+	+	120	40	+	4	2	1	-
	26	-	+	+	120	40	+	4	2	2	-
	39	-	+	+	120	40	+	4	1	3	-
right	3	-	+	+	120	60	+	2	3	0	-
	6	-	+	+	120	60	+	4	2	1	-
	12	-	+	+	120	60	+	4	2	1	-
	26	-	+	+	120	60	+	4	2	2	-
	39	-	+	+	120	60	+	4	1	3	-

5.45 (6 y.o., gelding, previous injury bilateral, moderate/moderate 10 months off, raced 3 times).

left	1	-	+	+	140	60	+	1	4	0	+
	26	-	+	+	140	60	+	4 + 5	2	3	+
right	1	-	+	+	140	75	+	1	4	0	+
	26	-	+	+	140	75	+	3 + 5	2	3	+

5.46 (6 y.o., mare, left, severe, retired).

	12	+	+	+	220	100	+	3	*	0	-
	26	+	+	+	220	100	+	2	*	1	+
	36	+	+	+	220	100	+	2 + 5	*	2	+
	52	+	+	+	220	100	+	2 + 5	*	2	+
	60	+	+	+	220	100	+	2 + 5	*	3	+

5.47 (5 y.o., mare, right, moderate, retired).

	26	-	+	+	120	75	+	4 + 5	2	2	+/-

5.48 (5 y.o., gelding, left, severe, 24 months off, raced once).

	1	+	+	+	220	100	+	3	*	0	+/-
	4	+	+	+	220	100	+	3	*	0	+/-
	12	+	+	+	220	100	+	3 + 5	*	1	+/-
	26	+	+	+	220	100	+	3 + 5	*	2	+
	36	+	+	+	220	100	+	3 + 5	*	2	+
	52	+	+	+	220	100	+	3 + 5	*	2	+
	72	+	+	+	220	100	+	4 + 5	*	2	+

5.49 (6 y.o., gelding, left, severe, retired).

left	1	+	+	+	220	100	+	3	*	0	+
	4	+	+	+	220	100	+	3	*	0	+
	12	+	+	+	220	100	+	4 + 5	*	1	+
	26	+	+	+	220	100	+	4 + 5	*	2	+
	36	+	+	+	220	100	+	4 + 5	*	2	+
	52	+	+	+	220	100	+	4 + 5	*	2	+

5.50 (7 y.o., gelding, previous injury, bilateral, severe/severe, retired).

left	12	+	+	+	220	100	+	4 + 5	*	1	+
	26	+	+	+	220	100	+	4 + 5	*	2	+
	36	+	+	+	220	100	+	4 + 5	*	2	+
	52	+	+	+	220	100	+	4 + 5	*	2	+
right	12	+	+	+	220	100	+	4 + 5	*	1	+
	26	+	+	+	220	100	+	4 + 5	*	2	+
	36	+	+	+	220	100	+	4 + 5	*	2	+
	52	+	+	+	220	100	+	4 + 5	*	2	+

5.51 (5 y.o., gelding, bilateral, moderate/moderate retired).

left	1	+	+	+	220	100	+	3	*	0	+	
	4	+	+	+	220	100	+	3	*	0	+	
	12	+	+	+	220	100	+	3 + 5	*	1	+	
	26	+	+	+	220	100	+	3 + 5	*	2	+	
	36	+	+	+	220	100	+	3 + 5	*	2	+	
	52	+	+	+	220	100	+	3 + 5	*	2	+	
	72	+	+	+	220	100	+	4 + 5	*	2	+	

5.52 (6 y.o., gelding, no previous injury, right, mild 11 months off, trained, recurred).

	3	-	+	+	120	40	+	2	3	0	-	
	4	-	+	+	120	40	+	2	3	0	-	
	5	-	+	+	120	40	+	2	2	0	-	
	6	-	+	+	120	40	+	4	2	1	-	
	12	-	+	+	120	40	+	4	2	1	-	
	26	-	+	+	120	40	+	4	2	2	-	
	39	-	+	+	120	40	+	4	1	3	-	

5.53 (6 y.o., gelding, no previous injury, bilateral, mild/mild, 12 months off, raced twice).

left	1	-	+	-	60	25	+	2	3	2	-	
	4	-	+	-	60	25	+	2	3	2	-	
	12	-	+	-	60	25	+	2	2	3	-	
	26	-	+	-	60	25	+	2	1	3	-	
right	1	-	+	-	40	25	-	2	3	2	-	
	4	-	+	-	40	25	-	2	3	2	-	
	12	-	+	-	40	25	-	2	1	3	-	
	26	-	+	-	40	25	-	2	*	4	-	

5.54 (7 y.o., gelding, no previous injury, left, moderate, 11 months off, training).

	1	-	+	+	120	75	+	1	4	0	-	
	2	-	+	+	120	75	+	1	4	0	-	
	3	-	+	+	120	75	+	1	4	0	-	
	4	-	+	+	120	75	+	3	3	0	-	
	12	-	+	+	120	75	+	3	3	1	-	
	26	-	+	+	120	75	+	4 + 5	2	2	+/-	
	36	-	+	+	120	75	+	4 + 5	1	3	+/-	

5.55 (10 y.o., gelding, previous injury, bilateral, severe/mild, 9 months off, training).

left	2	+	+	+	200	95	+	3	*	0	+	
	4	+	+	+	200	95	+	3	*	0	+	
	8	+	+	+	200	95	+	4	*	1	+	
	26	+	+	+	200	95	+	4 + 5	*	3	+	#d
right	2	-	+	-	40	25	+	2	3	2	+/-	
	4	-	+	-	40	25	+	2	3	2	+/-	
	8	-	+	-	40	25	+	2	1	3	+/-	
	26	-	+	-	40	25	+	2	*	4	+/-	

5.56 (9 y.o., mare, previous injury, right, severe, retired).

2	+	+	+	180	95	+	3	4	0	+	
3	+	+	+	180	95	+	3	4	0	+	
4	+	+	+	180	95	+	3	4	0	+	
8	+	+	+	180	95	+	3	4	0	+	
12	+	+	+	180	95	+	3 + 5	3	1	+	
26	+	+	+	180	95	+	3 + 5	3	2	+	
36	+	+	+	180	95	+	4 + 5	2/3	2	+	#d
52	+	+	+	180	95	+	4 + 5	2/3	3/2	+	#d
64	+	+	+	180	95	+	4 + 5	2/3	3/2	+	#d
80	+	+	+	180	95	+	4 + 5	2/3	3/2	+	#d

5.57 (5 y.o., mare, no previous injury, left, mild, outcome unknown).

4	-	+	-	80	30	+	1	4	0	-	
8	-	+	-	80	30	+	2	4	1	-	
26	-	+	-	80	30	+	2	2	4	-	

5.58 (5 y.o., gelding, no previous injury, right, severe, retired).

1	-	+	+	80	100	+	1	4	0	+	#8
4	-	+	+	80	100	+	1	4	0	+	
12	+	+	+	220	100	+	3 + 5	*	0	+	
26	+	+	+	220	100	+	4 + 5	*	1	+	#4

5.59 (4 y.o., gelding, no previous injury, right, mild, outcome unknown).

1	-	+	-	60	25	+	2	3	2	-	
4	-	+	-	60	25	+	2	3	2	-	
12	-	+	-	60	25	-	2	3	2	-	
16	-	+	-	60	25	-	2	3	2	-	

5.60 (4 y.o., gelding, previous injury, bilateral, severe/mild, retired).

left	1	+	+	+	220	100	+	3	*	0	+
	2	+	+	+	220	100	+	3	*	0	+/-
	3	+	+	+	220	100	+	3	*	0	+/-
	4	+	+	+	220	100	+	3	*	0	+/-
	12	+	+	+	220	100	+	4 + 5	*	1	+
	26	+	+	+	220	100	+	4 + 5	*	2	+
right	1	-	+	-	40	30	+	1	4	0	-
	4	-	+	-	40	30	+	1	4	0	-
	8	-	+	-	40	30	+	2	3	0	-
	12	-	+	-	40	30	+	2	2	1	-
	26	-	+	-	40	30	+	2	2	3	-

5.61 (6 y.o., gelding, no previous injury, bilateral, moderate/mild, 6 months off, trained, recurred).

left	1	-	+	+	120	65	+	1	4	0	-
	4	-	+	+	120	65	+	1	4	0	-
	6	-	+	+	120	65	+	3	4	0	-
	12	-	+	+	120	65	+	3	4	1	-
	26	-	+	-	100	65	+	2 + 5	2	3	-
	36	-	+	-	100	65	+	2 + 5	1	3	-
right	1	-	+	-	80	40	+	1	4	2	-
	4	-	+	-	80	40	+	2	3	2	-
	12	-	+	-	80	40	+	2	2	3	-
	26	-	+	-	80	40	+	2	2	3	-
	36	-	+	-	80	40	+	2	1	3	-

5.62 (7 y.o., gelding, previous injury, bilateral, severe/moderate, retired).

left	1	+	+	+	220	95	+	3	3	0	+
right	1	-	+	+	120	75	-	1	4	0	-

5.63 (8 y.o., gelding, previous injury, bilateral, severe/mild, retired).

left	1	+	+	+	220	100	+	3	*	0	+
right	1	-	+	-	60	25	-	2	4	0	-

5.64 (7 y.o., mare, bilateral, moderate/moderate retired).

left	4	-	+	+	80	40	-	2	4	0	-
right	4	-	+	+	140	50	+	1	4	0	-

5.65 (7 y.o., mare, bilateral, moderate/mild, retired).

left	1	-	+	+	60	40	-	2	4	0	-
right	1	-	+	+	140	60	+	1	4	0	-

5.66 (6 y.o., gelding, bilateral, severe/mild, retired).

left	1	-	+	+	60	40	-	2	4	0	-
right	1	+	+	+	220	100	+	3	*	0	-

5.67 (5 y.o., gelding, bilateral, severe/mild, retired).

left	1	-	+	+	60	25	-	2	4	0	-
right	1	+	+	+	220	100	+	3	*	0	-

5.68 (7 y.o., mare, bilateral, severe/mild, retired).

left	3	-	+	+	60	25	-	2	4	0	-
right	3	+	+	+	220	100	+	3	*	0	-

5.69 (6 y.o., gelding, bilateral, severe/moderate, retired).

left	2	+	+	+	220	100	+	3	*	0	-
right	2	-	+	+	120	65	+	1	4	0	-

5.70 (6 y.o., gelding, bilateral, severe/mild, retired).

left	2	+	+	+	220	100	+	3	*	0	-
right	2	-	+	+	80	30	+	1	4	0	-

5.71 (7 y.o., gelding, left, mild, 6 months off, raced 4 times).

	8	-	+	-	60	30	+	2	4	1	-
	26	-	+	-	60	30	+	2	1	4	-

5.72 (5 y.o., mare, no previous injury, bilateral, moderate/mild, retired).

left	1	-	+	+	120	75	+	1	4	0	-	
	26	-	+	+	120	75	+	4 + 5	3	3	-	
	52	-	+	+	120	75	+	2 + 5	1	4	-	
right	1	-	+	+	40 +	25	+	2 + 1	4	0	-	(1)
	26	-	+	+	40	25	+	2	3	4	-	
	52	-	+	+	*	*	-		*	4	-	

5.73 (6 y.o., gelding, previous injury, left, mild, 8 months off, raced 4 times).

	1	-	+	-	80	30	+	2	4	0	-
	8	-	+	-	80	30	+	2	4	1	-
	26	-	+	-	80	30	+	2	1	4	-

5.74 (4 y.o., gelding, right, moderate, outcome unknown).

	1	-	+	+	120	75	+	1	4	0	-

5.75 (5 y.o., mare, bilateral, severe/moderate, retired).

	4	-	+	+	180	85	+	3	4	0	+
	8	-	+	+	180	85	+	3	3	0	+
	12	-	+	+	180	85	+	4	3	1	+
	26	-	+	+	180	85	+	4 + 5	2	2	+
	37	-	+	+	180	85	+	4 + 5	1	2	+
	52	-	+	+	180	85	+	4 + 5	1	3	+
	4	-	+	+	120	65	+	1	4	0	+
	8	-	+	+	120	65	+	3	3	0	+
	12	-	+	+	120	65	+	4	3	1	+
	26	-	+	+	120	65	+	4 + 5	2	2	+
	37	-	+	+	120	65	+	4 + 5	1	2	+
	52	-	+	+	120	65	+	4 + 5	1	3	+

5.76 (5 y.o., gelding, left, severe, retired).

	1	-	+	+	160	80	+	1	4	0	-
	4	-	+	+	160	80	+	1	4	0	-

5.77 (7 y.o., gelding, left, mild, outcome unknown).
3 - + + 100 60 + 1 4 0 -

5.78 (5 y.o., gelding, left, mild, outcome unknown).
1 + + + 220 100 + 3 0 -

5.79 (4 y.o., mare, left, mild, outcome unknown).

12	-	+	-	60	50	+	2 + 5	3	2	

5.80 (7 y.o., mare, no previous injury, left, moderate, outcome unknown).

3	-	+	+	100	60	+	1	4	0	-

5.81 (7 y.o., gelding, previous injury, right, severe, outcome unknown).

2	+	+	+	220	100	+	3		0	-

5.82 (6 y.o., gelding, right, severe, outcome unknown).

1	+	+	+	220	100	+	3		0	-

5.83 (5 y.o., gelding, left, mild, outcome unknown).

26	-	+	-	100	65	+	2 + 5	2	3	-

5.84 (6 y.o., mare, no previous injury, right, moderate, outcome unknown).

1	-	+	-	120	50	-	1	4	0	-
5	-	+	-	120	50	-	3	3	0	-
12	-	+	-	120	50	-	3	3	1	-

5.85 (5 y.o., gelding, no previous injury, left, mild outcome unknown).

4	-	+	-	80	40	+	1	4	0	-

5.86 (5 y.o., gelding, no previous injury, left, mild, outcome unknown).

2	-	+	-	60	25	+	1	4	0	-

5.87 (8 y.o., gelding, right, moderate, outcome unknown).

24	-	+	-	100	65	+	2	2	3	-

5.88 (6 y.o., gelding, right, moderate, outcome unknown).

1	-	+	+	120	75	+	1	4	0	-

5.89 (7 y.o., gelding, right, mild, 9 months off, training).

52	+	+	+	220	100	+	2 + 5		2	+

5.90 (8 y.o., gelding, no previous injury, left, mild outcome unknown).

1	-	+	-	80	40	+	1	4	0	-
2	-	+	-	80	40	+	1	4	0	-
3	-	+	-	80	40	+	1	4	0	-
4	-	+	-	80	40	+	1	4	0	-
12	-	+	-	80	40	+	2	4	0	-
26	-	+	-	80	40	+	2	2	3	-

ABREVIATIONS USED IN APPENDIX 5.1

SDFT = superficial digital flexor tendon

L = lesion length (mms)

CS% = proportion of cross sectional area affected (%)

TE = tendon enlarged on palpation

ECHO = echogenicity (graded 1 - 5)

BORD = distinctness of lesion border (graded 1 - 4)

LIN = linear echo arrangement (graded 0 - 4)

PT = peritendinous lesions (+ = echogenic structure between the skin and SDFT, +/- = indistinct boundary between the S and DDFT's, - = no peritendinous abnormality)

* = not apparent

#d = well-defined hypoechoic region present in the distal third of the palmar metacarpal region

#m = well-defined hypoechoic region present in the middle third of the palmar metacarpal region

#1 = an irregular, asymmetric lesion within a chronic healed lesion

#2 = large skin lesions overlying the flexor tendons

#3 = diffuse reduction in echogenicity in the entire cross-section of the SDFT.

#4 = excessive, large aggregations of hyperechogenic material and anechoic foci appeared within the lesion.

#5 = new lesion within the original injury

#6 = annular ligament constriction

#7 = peritendinous hypoechogenicity increased in size

#8 = complete tendon rupture with intact skin

APPENDIX 6.1. DETAILS OF MICROWAVE THERMOGRAPHIC FINDINGS IN SIXTEEN HORSES WITH NORMAL FLEXOR TENDONS CONFIRMED BY ULTRASONOGRAPHIC EXAMINATION (GROUP 6.1).

	PRECLIPPING						POSTCLIPPING	
CASE NO.	MEAN LEFT (°C)	MEAN RIGHT (°C)	DIFF. IN MEAN (°C)	MAX. DIFF. (°C)	PROFILE L	R	MEAN LEFT	MEAN RIGHT
6.1.1	31.89	31.20	0.40	3.50	A	B	32.04	31.76
6.1.2	26.80	29.20	2.40	4.60	A	A	28.05	29.80
6.1.3	29.0	28.49	0.54	1.80	B	B	30.75	30.01
6.1.4	28.40	29.33	0.93	2.60	A	A	29.56	29.77
6.1.5	22.13	22.58	0.45	2.90	B	A	24.56	25.33
6.1.6	24.56	25.56	1.00	2.50	B	C	26.48	27.03
6.1.7	32.10	32.38	0.28	2.00	A	A	33.04	33.89
6.1.8	27.96	25.24	2.72	2.50	B	C	29.80	28.34
6.1.9	29.50	30.67	1.17	2.80	A	A	29.96	30.81
6.1.10	24.78	28.86	4.08	6.10	B	B	26.03	29.45
6.1.11	24.88	28.95	4.07	5.90	B	A	24.12	27.86
6.1.12	21.36	22.44	1.08	2.60	B	B	23.48	24.42
6.1.13	26.40	30.36	3.96	5.50	A	A	27.05	30.89
6.1.14	27.91	28.53	0.62	3.00	B	A	29.34	29.06
6.1.15	31.81	31.43	0.47	1.40	A	A	32.46	32.78
6.1.16	29.80	29.57	0.23	1.90	A	A	30.02	31.78

APPENDIX 6.2. DETAILS OF MICROWAVE THERMOGRAPHIC FINDINGS IN SIXTY-ONE HORSES WITH CLINICALLY NORMAL FLEXOR TENDONS (GROUP 6.2).

CASE NO.	MEAN LEFT TEMP (°C)	MEAN RIGHT TEMP (°C)	DIFF IN MEAN TEMP (°C)	MAX DIFF TEMP (°C)	PROFILE L	R
6.1.17	31.12	29.23	1.89	3.20	E	B
6.1.18	27.50	27.19	0.31	1.30	A	A
6.1.19	32.40	32.47	0.07	1.40	A	A
6.1.20	34.86	33.91	0.95	2.00	A	B
6.1.21	29.29	28.12	1.78	5.80	A	B
6.1.22	33.95	33.27	0.68	4.00	B	B
6.1.23	33.80	33.50	0.30	1.60	B	B
6.1.24	32.24	33.15	0.91	2.40	A	A
6.1.25	33.50	33.56	0.06	1.80	B	B
6.1.26	32.53	33.05	0.52	1.10	B	B
6.1.27	33.76	33.87	0.11	1.40	A	A
6.1.28	28.04	28.46	0.42	2.00	A	A
6.1.29	31.70	30.53	1.17	3.00	A	A
6.1.30	29.47	29.16	0.31	2.50	A	A
6.1.31	31.63	30.73	0.90	2.10	A	B
6.1.32	35.02	25.25	0.23	1.00	E	A
6.1.33	34.26	33.36	0.90	2.00	B	B
6.1.34	22.83	28.46	5.63	8.40	B	A

6.1.35	32.66	31.93	0.73	1.80	B	A
6.1.36	30.94	29.56	1.38	1.60	A	A
6.1.37	32.68	31.42	1.26	2.50	A	B
6.1.38	33.19	31.65	1.54	5.10	B	B
6.1.39	32.85	32.25	0.40	1.20	A	A
6.1.40	32.06	31.76	0.30	1.00	A	A
6.1.41	33.50	33.49	0.01	0.80	A	A
6.1.42	32.98	32.63	0.35	1.40	A	A
6.1.43	32.72	32.19	0.53	1.00	B	B
6.1.44	35.06	34.46	0.60	0.90	B	C
6.1.45	29.06	29.46	0.40	1.60	A	A
6.1.46	33.90	36.30	2.40	5.00	B	A
6.1.47	33.30	33.09	0.21	1.70	A	A
6.1.48	33.70	33.22	0.48	1.60	B	B
6.1.49	32.00	31.96	0.04	3.50	B	A
6.1.50	32.95	32.85	0.10	0.50	E	E
6.1.51	29.01	27.96	1.05	3.00	B	A
6.1.52	34.46	34.72	0.26	1.30	E	B
6.1.53	33.69	33.94	0.25	1.20	B	B
6.1.54	30.30	29.45	0.85	4.20	B	B
6.1.55	32.33	32.30	0.03	0.80	A	B
6.1.56	31.08	30.34	0.74	3.00	B	B
6.1.57	34.09	34.55	0.46	1.10	B	B
6.1.58	33.68	33.14	0.54	2.00	A	B
6.1.59	35.06	35.56	0.50	2.00	B	E
6.1.60	33.46	33.47	0.01	0.40	B	B
6.1.61	30.31	30.13	0.08	2.20	A	A
6.1.62	32.36	32.53	0.17	1.20	B	A
6.1.63	35.01	33.59	1.42	2.50	A	A
6.1.64	32.10	31.96	0.14	4.00	A	A
6.1.65	32.83	33.76	0.93	1.00	A	A
6.1.66	32.76	32.13	0.63	2.90	A	B
6.1.67	30.00	31.48	1.48	3.00	B	A
6.1.68	31.16	31.58	0.42	1.80	B	B
6.1.69	32.15	31.86	0.29	2.00	A	A
6.1.70	33.68	32.84	0.84	0.90	B	B
6.1.71	28.05	27.66	0.39	1.90	A	A
6.1.72	31.00	30.90	0.10	1.30	B	B
6.1.73	32.69	32.25	0.44	1.70	A	A
6.1.74	32.21	32.30	0.07	0.90	A	B
6.1.75	32.18	32.13	0.05	1.30	A	A
6.1.76	35.46	35.13	0.33	1.50	C	A
6.1.77	31.67	32.68	1.01	3.00	A	B

APPENDIX 6.3. THE DIAGNOSIS AND MICROWAVE THERMOGRAPHIC DATA RECORDED FROM GROUP 6.10: 12 HORSES WITH SOFT TISSUE INJURIES IN THE METACARPAL REGION.

CASE	LIMB AFFECTED	INJURY	MEAN LEFT TEMP (°C)	MEAN RIGHT TEMP (°C)	DIFF. IN MEAN TEMP (°C)	MAX DIFF TEMP (°C)	PROFILE L	R
6.2.57	LEFT	ICL	30.90	31.70	0.80	2.30	C	A
6.2.58	RIGHT	ICL	26.50	27.60	1.10	2.60	B	C
6.2.59	RIGHT	ICL	32.86	32.50	0.36	2.90	B	B
6.2.60	LEFT	ICL	30.76	30.40	0.36	0.90	B	B
6.2.61	RIGHT	ICL	26.70	29.00	2.30	4.30	A	A
6.2.62	LEFT	S/C SWELL	31.38	29.23	2.15	5.70	F	C
6.2.63	LEFT	S/C SWELL	31.96	31.16	0.80	1.60	F	A
6.2.64	RIGHT	S/C SWELL	29.54	31.44	1.90	3.00	F	C
6.2.65	LEFT	S/C SWELL	27.90	27.26	0.64	3.40	B	B
6.2.66	RIGHT	SKIN WOUND	28.50	26.05	2.45	6.80	A	F
6.2.67	LEFT	SKIN WOUND	32.13	33.77	1.64	2.90	C	D
6.2.68	RIGHT	SUSPENSORY	29.71	27.20	2.57	0.90	B	C

ICL = inferior check ligament injury
S/C SWELL = soft tissue swelling of subcutaneous tissues
SUSPENSORY = suspensory ligament injury

APPENDIX 6.4. THE MICROWAVE THERMOGRAPHIC DATA RECORDED FROM GROUP 6.3: 28 HORSES WITH SUPERFICIAL DIGITAL FLEXOR TENDON INJURY OF LESS THAN FOUR WEEKS' DURATION.

CASE	WEEK	LIMB	MEAN LEFT TEMP (°C)	MEAN RIGHT TEMP (°C)	DIFF IN MEAN TEMP (°C)	MAX DIFF IN TEMP (°C)	LOCATION OF MAX DIFF IN TEMP	PROFILE L	PROFILE R
6.2.1	1	LEFT	28.07	21.16	6.91	8.60	7L	C	A
6.2.2	1	LEFT	28.43	26.43	2.01	5.80	9L	C	A
6.2.2	1	LEFT	31.77	28.78	2.99	2.60	8L	D	F
6.2.3	4	LEFT	34.06	31.33	2.70	3.10	3L	D	C
6.2.4	2	BOTH	32.06	31.44	0.62	1.40	10L	C	C
6.2.4	3	BOTH	31.44	30.47	0.97	2.30	6L	C	F
6.2.5	4	LEFT	23.76	21.59	2.17	2.50	7L	B	B
6.2.6	1	RIGHT	26.36	32.30	5.94	8.40	9R	B	C
6.2.6	2	RIGHT	25.78	30.66	4.88	7.30	8R	B	C
6.2.6	3	RIGHT	27.43	32.71	5.28	6.70	8R	B	C
6.2.6	4	RIGHT	21.33	30.60	9.27	11.50	10R	A	E
6.2.6	4	RIGHT	22.06	30.36	8.30	10.40	10R	A	A
6.2.7	1	LEFT	34.81	33.50	1.31	2.20	10L	C	C
6.2.8	2	BOTH	26.7	25.61	1.12	4.10	6L	C	B
6.2.9	2	BOTH	31.67	32.06	0.39	3.10	3R	A	A
6.2.10	1	RIGHT	25.40	29.00	3.60	5.40	9R	B	C
6.2.11	1	RIGHT	25.43	31.69	3.26	7.40	6R	D	D
6.2.11	2	RIGHT	25.65	31.99	6.34	8.30	6R	B	B
6.2.11	2	RIGHT	30.30	33.80	3.77	5.80	7R	D	C
6.2.11	3	RIGHT	29.31	32.87	3.56	5.90	6R	D	D
6.2.12	1	RIGHT	16.85	27.80	10.95	13.10	7R	B	C
6.2.13	3	RIGHT	26.03	35.27	9.22	12.00	9R	B	C
6.2.14	4	RIGHT	18.81	29.83	11.02	12.60	10R	B	C
6.2.15	1	RIGHT	32.93	32.99	0.06	1.60	3R	A	D
6.2.16	1	LEFT	34.90	27.61	7.20	10.20	7L	C	A
6.2.16	1	LEFT	36.00	31.57	4.43	7.10	7L	C	A
6.2.16	2	LEFT	30.96	29.52	1.44	3.20	7L	C	A
6.2.16	3	LEFT	32.79	26.85	5.94	6.90	6L	C	A
6.2.16	3	LEFT	29.24	24.36	4.88	6.30	7L	D	A
6.2.16	4	LEFT	31.61	24.66	6.95	8.20	9L	D	E

6.2.16	4	LEFT	31.80	22.90	8.90	10.10	8L	C	B
6.2.17	2	BOTH	31.88	31.10	0.78	1.80	7L	F	A
6.2.17	3	BOTH	35.13	31.35	3.78	7.20	11L	D	B
6.2.17	4	BOTH	34.17	33.51	0.66	1.90	11L	D	B
6.2.33	2	LEFT	30.02	31.05	1.03	1.90	11R	D	D
6.2.34	4	BOTH	33.52	33.18	0.34	0.40	7L	C	C
6.2.35	2	BOTH	22.87	21.06	1.81	2.60	9L	F	F
6.2.38	1	BOTH	21.33	22.15	0.82	2.90	7L	B	F
6.2.39	2	LEFT	24.09	23.64	0.45	2.40	7L	F	B
6.2.40	2	BOTH	26.73	25.61	1.12	4.10	6L	C	B
6.2.41	1	LEFT	30.83	24.30	6.53	9.20	6L	C	B
6.2.41	2	LEFT	32.28	22.58	9.70	13.80	8L	C	B
6.2.42	4	BOTH	22.26	29.80	7.54	9.80	7L	C	B
6.2.49	1	LEFT	28.97	28.10	0.87	6.10	12L	D	B
6.2.50	1	RIGHT	25.35	29.00	3.65	5.40	9R	B	C
6.2.51	1	RIGHT	27.83	26.84	0.99	4.00	7R	A	C
6.2.51	3	RIGHT	22.50	27.30	4.80	9.60	5R	B	C
6.2.51	4	RIGHT	27.90	32.39	4.49	6.40	5R	A	F

APPENDIX 6.5. THE MICROWAVE THERMOGRAPHIC DATA RECORDED FROM GROUP 6.4: 20 HORSES WITH SUPERFICIAL DIGITAL FLEXOR TENDON INJURY OF FIVE TO EIGHT WEEKS' DURATION.

CASE	WEEK	LIMB	MEAN LEFT TEMP (°C)	MEAN RIGHT TEMP (°C)	DIFF IN MEAN TEMP (°C)	MAX DIFF IN TEMP (°C)	LOCATION OF MAX DIFF IN TEMP	PROFILE L	R
6.2.4	5	BOTH	26.03	25.44	0.60	1.50	7L	B	B
6.2.4	5	BOTH	22.07	20.98	1.09	2.00	9L	B	B
6.2.4	5	BOTH	21.79	24.03	2.24	2.90	4R	B	B
6.2.4	6	BOTH	26.81	28.46	1.65	3.70	5R	B	F
6.2.5	5	LEFT	24.53	23.97	0.55	1.70	5R	B	B
6.2.9	6	BOTH	17.82	15.75	2.07	2.60	7L	B	B
6.2.9	8	BOTH	25.79	30.48	4.33	6.40	8L	B	B
6.2.10	5	RIGHT	21.79	33.13	11.34	13.00	7R	B	C
6.2.12	5	RIGHT	19.60	26.40	6.80	8.80	10R	B	B
6.2.12	8	RIGHT	18.40	21.30	2.90	4.90	9R	B	B
6.2.14	5	RIGHT	28.21	32.77	4.56	7.30	7R	A	C
6.2.14	6	RIGHT	34.55	36.50	1.95	2.30	10R	A	C
6.2.14	6	RIGHT	29.00	32.39	3.39	5.00	8R	D	A
6.2.14	7	RIGHT	21.40	29.33	7.93	10.00	9R	B	C
6.2.14	7	RIGHT	18.21	26.27	8.06	9.60	6R	A	F
6.2.14	8	RIGHT	21.18	27.33	6.15	8.10	6R	B	C
6.2.16	8	LEFT	29.12	24.24	4.88	6.30	8L	D	A
6.2.17	6	BOTH	33.87	32.86	1.01	3.10	12R	E	E
6.2.18	8	LEFT	33.68	33.76	0.08	2.50	3R	C	A
6.2.19	7	BOTH	31.89	30.25	1.64	4.00	9L	C	B
6.2.19	7	BOTH	23.99	24.10	0.11	3.30	8L	C	A
6.2.19	8	BOTH	27.69	29.23	1.54	2.40	6R	D	D
6.2.19	8	BOTH	27.05	25.09	1.97	2.80	8L	D	D
6.2.20	5	BOTH	32.76	31.39	0.78	1.60	10R	A	B
6.2.20	6	BOTH	29.76	31.39	1.63	1.30	8R	A	A
6.2.20	7	BOTH	30.59	29.58	1.10	3.40	8R	C	A
6.2.20	8	BOTH	34.36	34.46	0.10	2.10	1R	E	A
6.2.21	5	BOTH	22.58	23.76	1.18	3.70	8R	C	C
6.2.22	8	RIGHT	31.33	31.48	0.15	2.00	5R	C	C
6.2.23	6	LEFT	30.20	23.20	7.00	12.50	7L	C	B
6.2.23	7	LEFT	31.23	22.24	8.99	13.80	7L	C	B
6.2.23	8	LEFT	31.85	25.43	6.43	10.80	8L	C	B

6.2.34	5	BOTH	35.70	36.12	0.42	1.10	5R	C	C
6.2.34	6	BOTH	32.46	33.56	1.02	3.50	6R	C	C
6.2.34	7	BOTH	34.12	33.53	0.59	0.80	8L	C	C
6.2.34	8	BOTH	32.67	33.38	0.71	1.80	6R	D	C
6.2.35	5	BOTH	23.05	20.16	2.89	3.20	8L	F	B
6.2.37	8	RIGHT	33.25	33.02	0.23	2.40	4L	B	D
6.2.38	8	BOTH	28.85	31.19	2.25	3.90	9R	C	C
6.2.39	6	LEFT	30.49	29.50	1.01	4.70	10L	A	B
6.2.41	5	LEFT	31.46	20.27	11.13	15.00	9L	C	B

APPENDIX 6.6. THE MICROWAVE THERMOGRAPHIC DATA RECORDED FROM GROUP 6.5: 11 HORSES WITH SUPERFICIAL DIGITAL FLEXOR TENDON INJURY OF NINE TO 12 WEEKS' DURATION.

CASE	WEEK	LIMB	MEAN LEFT TEMP (°C)	MEAN RIGHT TEMP (°C)	DIFF IN MEAN TEMP (°C)	MAX DIFF IN TEMP (°C)	LOCATION OF MAX DIFF IN TEMP	PROFILE L	PROFILE R
6.2.1	12	LEFT	29.29	31.25	1.96	3.10	10R	C	D
6.2.11	9	RIGHT	30.34	31.76	1.42	5.10	1R	D	F
6.2.14	14	RIGHT	34.55	36.50	1.95	4.00	11R	D	D
6.2.17	10	BOTH	29.96	32.36	2.40	3.50	4R	D	C
6.2.19	9	BOTH	31.36	31.55	0.19	2.40	13R	A	A
6.2.19	9	BOTH	27.20	23.50	3.70	5.50	8R	C	B
6.2.19	10	BOTH	27.50	26.17	1.33	2.60	8R	D	D
6.2.19	10	BOTH	26.83	27.33	0.50	2.40	3R	C	A
6.2.20	9	BOTH	29.65	29.94	0.29	1.20	13R	A	A
6.2.22	8	RIGHT	32.00	35.15	3.15	5.30	6R	A	C
6.2.22	8	RIGHT	28.00	31.70	3.70	5.20	11R	C	B
6.2.22	9	RIGHT	32.03	34.30	2.27	3.50	9R	B	C
6.2.22	10	RIGHT	23.93	29.80	5.87	8.30	9R	B	B
6.2.22	10	RIGHT	23.93	29.80	6.87	8.10	10R	C	D
6.2.24	12	LEFT	30.92	30.67	0.60	0.70	5L	B	B
6.2.33	10	LEFT	26.92	30.06	3.14	2.90	7R	A	A
6.2.38	11	BOTH	24.50	28.57	5.99	6.80	9R	C	C
6.2.43	9	RIGHT	34.70	35.16	0.40	0.60	9R	F	F

APPENDIX 6.7. THE MICROWAVE THERMOGRAPHIC DATA RECORDED FROM GROUP 6.6: 13 HORSES WITH SUPERFICIAL DIGITAL FLEXOR TENDON INJURY OF 13 TO 16 WEEKS' DURATION.

CASE	WEEK	LIMB	MEAN LEFT TEMP (°C)	MEAN RIGHT TEMP (°C)	DIFF IN MEAN TEMP (°C)	MAX DIFF IN TEMP (°C)	LOCATION OF MAX DIFF IN TEMP	PROFILE L	PROFILE R
6.2.2	16	LEFT	31.09	33.43	2.34	4.90	7R	A	A
6.2.9	15	BOTH	23.03	22.26	0.77	6.80	4L	B	B
6.2.14	16	RIGHT	24.66	31.08	6.42	7.80	11R	C	C
6.2.17	14	BOTH	22.36	26.04	3.68	5.10	6R	A	A
6.2.19	14	BOTH	24.66	31.08	6.42	7.80	11R	C	C
6.2.21	15	BOTH	23.98	30.78	6.80	10.20	6R	A	A
6.2.25	16	LEFT	30.76	30.05	0.71	3.90	1L	A	A
6.2.34	16	BOTH	31.01	31.52	0.51	1.10	7R	D	C
6.2.35	13	BOTH	18.24	18.21	0.03	0.90	4L	B	B
6.2.36	16	BOTH	35.20	36.13	0.93	2.10	4R	F	E
6.2.44	13	LEFT	34.10	32.71	1.39	1.80	6L	D	D
6.2.52	16	RIGHT	30.24	24.51	5.69	6.30	7L	F	B
6.2.53	16	RIGHT	29.64	32.48	2.84	3.60	7R	D	F

APPENDIX 6.8. THE MICROWAVE THERMOGRAPHIC DATA RECORDED FROM GROUP 6.7: 16 HORSES WITH SUPERFICIAL DIGITAL FLEXOR TENDON INJURY OF 17 TO 28 WEEKS' DURATION.

CASE	WEEK	LIMB	MEAN LEFT TEMP (°C)	MEAN RIGHT TEMP (°C)	DIFF IN MEAN TEMP (°C)	MAX DIFF IN TEMP (°C)	LOCATION OF MAX DIFF IN TEMP	PROFILE L	PROFILE R
6.2.6	26	RIGHT	30.73	30.92	0.19	1.10	8L	A	A
6.2.12	18	RIGHT	28.83	31.76	2.93	4.70	7R	C	C
6.2.16	28	LEFT	35.71	33.07	2.64	5.00	5L	E	A
6.2.19	26	BOTH	25.45	29.10	3.65	4.10	5R	D	D
6.2.21	21	BOTH	29.73	30.66	0.93	2.60	2R	B	B
6.2.21	28	BOTH	30.03	29.93	0.10	1.20	4L	A	A
6.2.24	24	LEFT	31.10	33.03	2.10	0.40	4L	B	B
6.2.25	24	LEFT	32.57	29.52	3.05	4.90	3L	A	D
6.2.26	26	LEFT	30.23	32.00	1.77	2.70	4R	D	E
6.2.37	20	BOTH	26.28	28.84	2.56	3.70	9R	F	F
6.2.38	24	BOTH	25.50	21.20	4.30	4.70	8L	C	F
6.2.42	24	BOTH	15.70	14.80	0.90	3.60	4L	B	B
6.2.45	22	LEFT	34.30	33.05	1.25	2.30	8L	C	B
6.2.46	20	RIGHT	30.70	32.26	1.56	5.40	2R	D	A
6.2.54	26	RIGHT	31.80	32.90	1.10	1.50	4R	E	E
6.2.55	26	RIGHT	34.00	33.80	0.20	1.00	8L	E	B
6.2.58	26	BOTH	32.98	32.80	0.10	0.50	6L	B	B

APPENDIX 6.9. THE MICROWAVE THERMOGRAPHIC DATA RECORDED FROM GROUP 6.8: 18 HORSES WITH SUPERFICIAL DIGITAL FLEXOR TENDON INJURY OF 29 TO 52 WEEKS' DURATION.

CASE	WEEK	LIMB	MEAN LEFT TEMP (°C)	MEAN RIGHT TEMP (°C)	DIFF IN MEAN TEMP (°C)	MAX DIFF IN TEMP (°C)	LOCATION OF MAX DIFF IN TEMP	PROFILE L	R
6.2.3	36	LEFT	32.32	33.39	1.00	1.40	8R	C	C
6.2.3	40	LEFT	31.31	31.24	0.10	2.00	6R	A	A
6.2.6	38	RIGHT	32.97	32.63	0.34	0.80	6L	B	A
6.2.12	38	RIGHT	31.70	31.53	0.17	1.50	9L	A	A
6.2.16	40	LEFT	31.51	32.06	0.55	1.70	3R	B	B
6.2.27	44	RIGHT	34.28	33.78	0.50	1.20	6L	B	A
6.2.33	38	LEFT	29.97	30.08	0.11	1.00	10R	B	B
6.2.35	37	BOTH	29.70	29.51	0.27	2.00	5L	D	A
6.2.36	44	BOTH	28.80	31.82	3.02	4.00	7R	D	F
6.2.38	30	BOTH	21.08	23.70	2.62	5.30	5L	F	C
6.2.38	34	BOTH	31.64	32.06	0.42	1.10	8R	A	F
6.2.42	49	BOTH	29.01	32.06	2.99	3.80	4R	D	F
6.2.43	40	RIGHT	25.06	25.17	0.11	2.90	7R	A	A
6.2.44	32	LEFT	27.20	23.50	3.70	7.80	6L	F	A
6.2.44	38	LEFT	21.36	22.00	0.64	1.30	4R	A	A
6.2.44	40	LEFT	22.73	18.82	3.91	7.40	9L	F	A
6.2.45	45	LEFT	28.56	29.79	1.20	2.50	7R	A	A
6.2.46	38	RIGHT	31.71	32.24	0.53	2.10	4R	E	A
6.2.47	36	BOTH	26.85	32.95	6.10	9.80	6R	D	C
6.2.48	32	RIGHT	35.31	35.21	0.10	2.10	4L	E	C
6.2.51	34	RIGHT	31.30	32.80	1.50	1.90	6R	F	A
6.2.52	30	RIGHT	30.08	31.85	1.77	2.60	5R	A	A
6.2.52	48	RIGHT	20.11	28.27	8.16	11.00	8R	E	C

APPENDIX 6.10. THE MICROWAVE THERMOGRAPHIC DATA RECORDED FROM GROUP 6.9: 13 HORSES WITH SUPERFICIAL DIGITAL FLEXOR TENDON INJURY OF GREATER THAN 52 WEEKS' DURATION.

CASE	WEEK	LIMB	MEAN LEFT TEMP (°C)	MEAN RIGHT TEMP (°C)	DIFF IN MEAN TEMP (°C)	MAX DIFF IN TEMP (°C)	LOCATION OF MAX DIFF IN TEMP	PROFILE L	PROFILE R
6.2.6	52	RIGHT	25.04	29.91	4.87	6.30	6R	B	F
6.2.27	78	RIGHT	21.41	19.15	2.26	3.70	6L	B	A
6.2.27	86	RIGHT	30.37	30.83	0.46	2.10	11R	B	B
6.2.27	92	RIGHT	31.15	33.17	2.02	4.10	9R	B	B
6.2.27	100	RIGHT	32.69	32.90	0.21	0.70	2R	E	E
6.2.27	104	RIGHT	22.86	22.90	0.04	0.60	11R	B	B
6.2.28	52	RIGHT	31.33	32.82	1.51	2.00	5R	A	A
6.2.29	52	BOTH	30.90	32.88	1.90	2.10	8R	D	C
6.2.29	70	BOTH	34.18	35.30	1.20	1.80	8R	E	E
6.2.29	84	BOTH	31.33	29.58	1.75	1.70	8L	A	A
6.2.29	90	BOTH	29.50	30.20	0.70	3.80	8R	A	B
6.2.30	52	BOTH	32.90	33.80	0.90	1.50	5R	E	E
6.2.31	52	LEFT	31.24	30.21	1.00	2.60	7L	D	B
6.2.32	52	LEFT	31.88	29.98	1.90	6.10	1R	B	D
6.2.32	74	LEFT	29.87	31.91	2.04	3.00	3R	E	B
6.2.32	80	LEFT	29.36	30.98	1.60	3.10	3R	E	B
6.2.32	92	LEFT	31.93	32.19	0.20	1.40	1R	E	E
6.2.32	104	LEFT	29.25	30.60	1.40	2.90	2R	A	A
6.2.32	110	LEFT	24.02	24.33	0.30	7.20	10L	A	C
6.2.36	56	BOTH	27.09	22.70	4.39	6.00	6L	A	A
6.2.36	60	BOTH	31.63	32.04	0.41	1.30	3R	B	B
6.2.36	72	BOTH	29.34	32.64	3.30	4.40	8R	D	D
6.2.45	40	LEFT	27.30	28.36	1.06	2.60	4R	A	A
6.2.45	60	LEFT	32.66	30.59	2.10	2.90	4L	E	F
6.2.46	52	RIGHT	25.60	27.80	2.20	4.00	6R	A	A
6.2.55	72	BOTH	27.53	29.65	2.12	3.50	3R	F	A
6.2.56	76	BOTH	30.20	30.80	0.60	2.30	3R	F	B
6.2.59	81	RIGHT	27.28	26.43	0.95	2.10	6L	B	B
6.2.59	85	RIGHT	28.77	24.18	4.50	11.90	10L	C	A

APPENDIX 6.11. MICROWAVE THERMOGRAPHIC DATA RECORDED F THIRTY-FOUR HORSES IN TRAINING OVER A THIRTEEN WEEK PERIOD

CASE NO.	WEEK NO.	MEAN LEFT TEMP (^{o}C)	MEAN RIGHT TEMP (^{o}C)	DIFF IN MEAN TEMP (^{o}C)	MAX DIFF TEMP (^{o}C)	PROFILE LEFT	RIGH
6.3.1	1	28.02	28.63	0.61	1.50	A	A
	2	32.73	32.74	0.01	0.90	A	B
	3	34.05	33.36	0.69	1.50	E	B
	4	33.49	33.20	0.29	1.90	C	A
	8	22.29	20.67	1.69	2.90	B	B
	13	34.70	34.19	0.51	3.00	A	B
6.3.1	1	28.02	28.63	0.61	1.50	A	A
	2	32.73	32.74	0.01	0.90	A	B
	3	34.05	33.36	0.69	1.50	E	B
	4	33.49	33.20	0.29	1.90	C	A
	8	22.29	20.67	1.69	2.90	B	B
	13	34.70	34.19	0.51	3.00	A	B
6.3.2	2	32.25	32.70	0.45	2.60	C	F
	3	35.64	35.23	0.41	2.60	E	B
	4	30.70	29.53	1.17	2.90	B	B
6.3.3	1	29.30	29.70	0.40	1.00	A	A
	2	32.82	32.37	0.45	1.20	A	A
6.3.4	1	31.16	31.50	0.34	2.10	E	A
	2	31.60	31.70	0.10	1.10	A	E
	3	36.40	35.30	1.10	1.80	E	E
	4	29.81	29.05	0.76	2.60	B	B
	8	31.82	30.39	1.43	4.40	A	A
	10	28.40	26.60	1.80	3.20	A	B
	11	30.86	30.03	0.83	2.00	A	A
	12	21.67	22.01	0.34	4.70	B	B
	13	29.80	28.50	1.30	3.30	A	B
6.3.5	5	29.06	27.99	1.07	3.50	F	A
	8	32.07	32.89	0.82	1.30	A	A
	10	26.66	26.56	0.10	4.00	B	B
	11	34.04	33.90	0.14	0.50	A	A
	12	32.18	31.62	0.56	1.90	A	A
	13	28.28	28.53	0.25	1.50	B	B
6.3.6	8	33.08	33.28	0.20	1.40	A	B
	10	33.62	33.64	0.02	1.40	B	A
	12	33.42	33.95	0.53	2.10	B	A
	13	33.83	33.57	0.26	1.30	A	A

6.3.7	1	30.35	30.84	0.49	1.10	A	A
	2	31.66	31.88	0.22	1.40	A	A
	3	33.77	33.50	0.27	2.40	B	A
	4	35.11	34.20	0.91	1.70	E	A
	5	26.25	25.48	0.77	2.80	B	B
	8	31.74	30.76	0.98	3.90	A	B
	10	30.08	30.26	0.18	2.90	A	B
	11	30.10	30.30	0.20	2.60	B	B
	12	28.31	30.07	1.76	4.10	B	B
	13	32.38	32.62	0.24	1.90	A	A
6.3.8	3	35.30	35.60	0.30	1.90	D	E
	4	34.92	34.02	0.90	1.50	A	A
	5	29.70	31.00	1.30	3.60	C	E
6.3.9	8	34.36	33.93	0.43	2.20	B	B
	11	32.60	32.71	0.11	1.20	A	A
	12	27.90	27.50	0.40	2.50	B	B
	13	31.73	32.56	0.83	2.40	A	A
6.3.10	8	28.96	28.90	0.06	2.30	B	B
	10	32.66	33.53	0.87	1.60	B	B
	11	33.50	33.80	0.30	1.50	A	A
	12	31.83	31.66	0.17	2.60	B	B
	13	32.03	32.46	0.43	4.00	B	B
6.3.11	1	28.19	25.10	3.09	7.00	B	B
	2	32.66	32.62	0.04	0.50	E	E
6.3.12	3	34.81	35.01	0.20	1.30	B	B
	4	35.21	33.19	2.02	3.20	B	E
	5	29.37	27.49	1.88	3.80	A	A
	10	33.91	33.60	0.31	1.00	A	A
6.3.13	2	32.49	33.00	0.51	1.90	F	B
	3	36.76	36.42	0.34	2.00	A	A
	4	34.26	34.70	0.44	2.90	A	A
	5	30.57	31.88	1.31	2.80	B	A
	8	32.04	33.17	1.13	2.60	B	A
	10	31.68	30.18	1.50	4.10	A	A
	11	34.07	34.01	0.06	0.90	B	B
	12	32.24	32.28	0.04	1.50	A	B
	13	30.57	31.53	0.96	1.70	A	A
6.3.14	1	30.49	29.86	0.63	2.20	A	A
	2	31.93	32.03	0.10	0.40	E	E
	3	35.30	34.56	0.74	1.60	B	C
	4	33.19	34.13	0.94	1.30	C	C

6.3.15	2	28.50	26.05	2.45	6.80	A	A
	3	29.35	28.55	0.80	2.60	B	B
	4	28.10	29.90	1.80	1.50	A	A
	5	28.93	29.90	0.97	3.00	A	A
	8	32.90	32.30	0.60	2.40	F	B
	10	29.57	30.18	0.61	3.90	A	A
	11	26.13	25.34	0.79	5.20	A	B
	12	27.57	20.09	7.48	12.20	B	B
	13	27.90	27.26	0.64	3.40	B	B
6.3.16	1	30.10	29.90	0.20	1.80	A	A
	2	31.58	31.94	0.36	0.90	A	A
	4	32.36	31.57	0.79	2.60	A	A
6.3.17	1	25.50	27.70	2.20	5.20	A	A
	2	32.83	33.16	0.33	0.70	E	E
	3	36.19	35.60	0.59	1.90	B	E
	4	34.50	34.06	0.44	1.20	A	A
	5	28.63	28.40	0.23	2.70	A	A
	8	33.74	33.79	0.05	1.00	B	A
	10	33.59	32.94	0.65	1.90	A	A
	12	23.20	28.11	4.91	10.70	B	C
	13	34.14	34.35	0.21	1.50	A	B
6.3.18	1	25.37	25.50	0.13	1.30	B	B
	2	32.92	32.81	0.11	0.40	B	B
	3	35.08	35.01	0.07	0.60	E	E
	4	32.91	32.26	0.65	1.70	C	B
	5	21.96	23.93	1.96	5.30	B	B
	8	21.30	21.87	0.57	2.20	B	B
6.3.19	1	29.27	31.00	1.73	2.30	A	A
	2	32.14	31.90	0.24	0.50	E	E
	3	34.55	34.43	0.12	0.50	A	A
	4	34.39	34.05	0.34	1.80	B	A
	5	28.06	27.76	0.30	3.30	A	A
	8	33.04	33.25	0.21	1.30	B	B
	10	32.74	33.20	0.46	1.00	B	A
	11	31.03	30.50	0.53	3.70	A	B
	13	32.73	33.00	0.27	0.90	A	A
6.3.20	1	31.92	31.30	0.62	3.30	D	F
	2	32.83	32.63	0.20	0.40	E	F
	3	35.81	36.07	0.26	2.80	B	A
	4	34.91	34.40	0.51	0.90	E	E
	8	31.16	30.24	0.92	1.50	A	A
	10	32.70	31.52	1.18	3.30	A	A
	11	33.63	31.74	1.89	4.10	A	F
	12	30.02	31.20	1.18	5.20	A	C
	13	30.08	31.03	0.95	3.50	A	F

6.3.21	1	26.63	28.18	1.55	3.50	B	A
	2	31.17	31.56	0.39	1.90	E	A
	3	31.44	31.28	0.16	2.80	B	B
	4	30.67	29.81	0.86	1.30	B	B
	5	31.43	30.51	0.92	1.40	A	A
	8	31.26	31.00	0.26	1.00	A	A
	10	32.01	31.73	0.28	1.80	A	B
	11	31.82	32.44	0.62	2.20	B	A
	12	21.98	22.68	0.70	5.20	B	B
	13	31.57	32.26	0.69	1.90	B	B
6.3.22	1	29.23	29.00	0.23	4.00	A	A
	2	32.56	32.25	0.31	0.90	E	B
	3	35.62	35.35	0.27	1.40	B	E
	4	35.25	34.15	1.10	1.30	A	A
	5	24.33	25.16	0.83	3.30	B	B
6.3.23	2	31.50	31.00	0.50	0.80	A	A
	3	33.94	32.96	0.98	1.20	B	A
	4	31.82	31.91	0.09	0.50	A	B
	5	25.09	22.84	2.25	4.90	B	B
	8	33.53	32.46	1.07	3.80	B	A
	10	32.06	30.91	1.15	2.80	A	B
	11	31.76	28.37	3.39	5.50	A	A
	12	32.59	29.43	3.16	6.30	B	B
	13	32.34	32.14	0.20	0.80	A	A
6.3.24	2	32.12	31.85	0.27	2.30	A	A
	3	35.63	35.09	0.54	1.70	B	F
	4	33.83	33.79	0.04	1.40	C	F
	5	29.76	29.84	0.08	2.00	A	A
	8	33.80	33.63	0.17	0.40	B	B
	11	30.93	30.03	0.90	3.10	A	A
	12	29.35	28.59	0.76	2.70	B	B
	13	32.78	32.25	0.53	3.80	A	B
6.3.25	2	32.00	30.75	1.25	3.10	A	E
	3	35.58	34.95	0.63	1.80	B	B
	4	34.03	33.31	0.72	3.00	B	B
	5	33.26	32.87	0.39	1.90	F	F
6.3.26	2	34.84	35.36	0.52	2.10	E	A
	3	34.86	34.47	0.39	1.70	A	F
	4	35.50	34.44	1.06	1.70	F	B
	5	30.20	29.87	0.33	3.10	F	A
	8	30.02	29.83	0.19	3.40	A	F
	11	31.93	30.60	1.33	5.00	A	B
	12	30.85	30.06	0.79	3.00	F	A
	13	32.43	31.06	1.37	4.40	A	A
6.3.27	2	34.84	35.80	0.96	3.20	D	E
	3	35.20	34.50	0.70	1.70	E	A
	4	34.30	33.51	0.79	1.60	A	B
	5	32.21	31.69	0.65	1.80	F	A
	8	32.09	31.56	0.53	4.10	F	C

	11	31.88	31.01	0.87	1.80	A	A
	12	31.99	32.07	0.08	1.40	A	F
	13	34.23	33.41	0.82	2.50	A	A
6.3.28	1	23.16	22.48	0.68	4.30	B	B
	2	32.68	32.15	0.53	1.50	E	B
	3	35.07	34.52	0.55	1.80	B	E
	4	34.48	33.98	0.50	1.30	A	A
	5	29.96	28.86	1.10	1.00	A	A
	8	32.35	31.72	0.63	2.50	B	A
	10	32.09	32.05	0.04	1.00	B	B
	11	28.68	29.46	0.78	3.70	A	A
	12	22.96	21.90	1.06	3.80	B	B
	13	31.50	31.65	0.15	2.10	A	A
6.3.29	1	32.51	31.92	0.59	1.40	E	D
	2	32.14	32.06	0.08	0.90	A	A
	3	31.49	35.30	3.81	7.10	B	C
	4	36.20	35.70	0.50	1.10	E	E
	5	27.53	27.68	0.15	0.30	E	E
	8	33.43	33.51	0.08	1.10	A	A
	10	32.35	31.50	0.85	3.00	A	B
	12	28.96	29.22	0.26	2.60	A	B
6.3.30	1	24.17	24.40	0.23	1.30	B	B
	2	30.40	30.12	0.28	1.30	A	B
	4	33.12	33.06	0.06	1.50	A	A
	5	26.90	28.09	1.19	1.80	B	B
6.3.31	1	28.76	27.77	0.99	4.90	A	A
	2	30.17	30.92	0.75	2.50	A	A
	3	29.98	29.53	0.45	2.60	B	B
	4	32.53	31.80	0.73	1.70	A	A
	5	34.24	32.71	1.53	2.50	C	E
6.3.32	2	32.22	32.82	0.60	2.00	B	B
	3	35.18	35.23	0.05	0.80	B	B
	4	34.41	33.92	0.49	1.10	B	F
	5	31.79	31.07	0.72	1.80	B	A
	8	31.56	31.62	0.06	3.20	A	A
	10	30.13	31.09	0.96	1.50	A	A
	11	30.13	30.47	0.34	1.20	A	A
	13	30.28	30.80	0.52	2.80	A	A
6.3.33	1	30.86	29.21	1.65	3.50	A	B
	2	32.09	31.16	0.93	1.80	A	B
	3	33.93	34.31	0.38	0.70	E	B
	4	27.73	33.23	5.50	8.60	B	A
	5	29.87	22.54	7.33	10.10	A	A
6.3.34	2	31.97	26.62	5.35	7.80	E	B
	3	35.24	34.83	0.41	1.20	C	B